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InvEnt 2019

18. 6. 2019, Žilina

Proceedings
of the Scientific International Conference
InvEnt 2019

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Title:	InvEnt 2019: Industrial Engineering – Invention for Enterprise
Kind of publication:	Proceedings
Publisher:	Wydawnictwo Akademii Techniczno-Humnistycznej w Bielsku-Białej, Willowa 2, 43-309 Bielsko-Biała. Tel.: 033 8279 268
Date of issue:	June 2019
Proceedings maker:	Ing. Róbert Hodoň, Ing. Blanka Horváthová
Cover and design:	Ing. Martin Gašo
Editor-in-chief of publishing:	doc. Ing. Martin Krajčovič, PhD.
Edition:	1st Edition
Range:	140 Pages
Link:	www.priemyselneinzinierstvo.sk
Font:	Times New Roman

InvEnt 2019 ISBN 978-83-66249-18-9

Book ISBN 978-83-66249-16-5

e-Book ISBN 978-83-66249-17-2
(www.priemyselneinzinierstvo.sk)

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Digital Twin, Digital Shadow, Digital Model, Manufacturing

Roman BAMBURA*, Erika SUJOVÁ**, Miroslav DADO***

EVOLUTION AND INTEGRATION OF DIGITAL TWIN

Abstract
This article provides basic information about development of DT concept. Firstly, history and development of DT is presented. Secondly, definitions for Digital Model (DM), Digital Shadow (DS) and Digital twin (DT) are given to better understand differences between these terms and to establish connections between them and to describe how they interact together. Finally benefits of DT concept are presented.

1. EVOLUTION OF DIGITAL TWIN

The term Digital Twin (DT) was first defined by Grieves [1] as "virtual, digital equivalent to physical product". Concept of DT was improved in 2005 by Grieves and classified into three categories which contains DT prototype, DT instance and DT aggregate [2]. Another breakthrough in DT's development came in 2010 when NASA defined DT in its research in 2010 and 2012 as "an integrated multi-physics, multi-scale, probabilistic simulation of vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its flying twin" [3] [4]. This moment in development of DT was crucial for future of this concept. DT was considered a key technology for the future of NASA vehicles as well as for the US. Air Force [3] [4]. Whitepaper published by Grieves in 2014, described the concept of DT, in three-dimensional structure. This concept involved a physical entity in a physical world, a virtual entity in a virtual world, and a connection of data and information between a physical and a virtual world. This resulted in DTs rapid increase in popularity not only in the aerospace

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industry but also in the automotive industry, healthcare and medicine [1]. The number of publications dealing with the DT concept has been growing in number in recent years and the popularity of this concept is constantly growing with biggest recorded increase in 2017 [5].

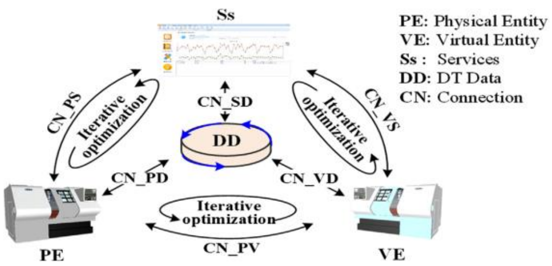

Fig. 1 Five-dimensional model of DT [6]

The ever-increasing demands of the market and customers and the increasing production demands have led to the improvement of the DT concept. In 2018 Tao et al. designed an extended version of a three-dimensional concept in which 2 new aspects were added, namely DT data and Services, creating a 5-dimensional DT concept illustrated in Fig. 1 [6]. Fig. 2 presents evolution of DT according to previously written knowledge about this concept.

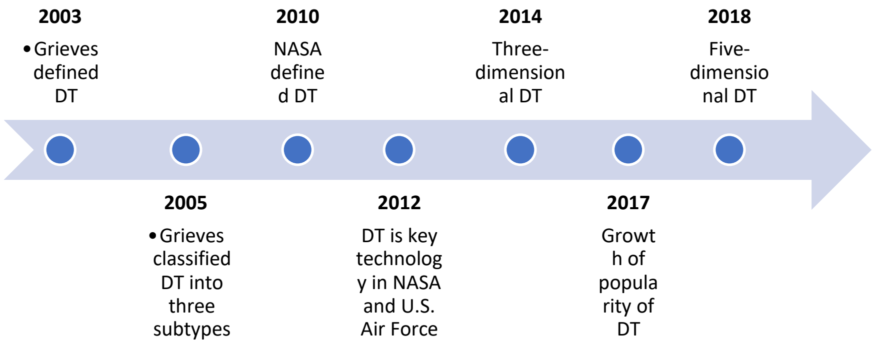

Fig. 2 Evolution of DT [7]

2. INTEGRATION OF DIGITAL TWIN

2.1. Digital Model, Digital Master (DM)

Digital model and Digital master are synonymously used terms for digital representation of a physical product, object or system that does not use and apply any form of automatic data exchange between the physical and virtual world. Data can be implemented for development and the creation of such models, but all data exchange is manual, so a change in the physical world has no direct effect on the virtual state [8]. DM plays important role in creation of DT where accurate models and 3D models are needed to create a realistic DT [9].

2.2. Digital Shadow (DS)

DS is understood as a form of operational data, status data, process data, etc. which every product or production system produces. DS is a data profile that couples with the corresponding entity throughout its lifecycle and carries all the data and knowledge to reflect the individual's shape and historical, current, and expected future status [10]. DS contains all of the information and data and connect physical world with virtual world which is necessary for gathering all of the important data and information which are implemented into virtual world from physical world [11].

2.3. Digital Twin (DT)

The DT consists of a DM, its individual DS and connections between them with use of sensors, data and integration technology [12]. DM design according to DS is necessary to be evaluated firstly for reliable simulation results of DT [10]. The virtual representation known as DT carries physical object data for its entire life cycle which is similar to the DS. Despite the similarities in the definitions of these two concepts, DT is superior to the DS in the following aspects:

- High-fidelity digital model is provided by DT to describe the subject;
- Manufacturing processes and activities can be validated prior to execution, reducing the risk of failure;
- Evaluation, optimization, and prediction can be enhanced by synchronization between the real and the virtual world;
- Data from the physical but also from the virtual world, and data derived from interactions between the two worlds provides complex, and more accurate and comprehensive information [7].

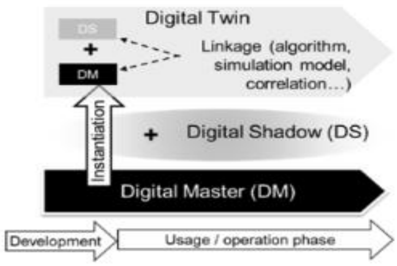

Fig. 3 Interaction between DT, DS and DM [10]

The main benefits of DT compared to DS and DM include:

- DT as multi-domain and ultra-high-fidelity model integrates different areas;
- DT combines multiple product activities like design, production and maintenance;
- DT is used for virtual mapping of physical products;
- Historical and current data can be used for prediction;
- DT can perceive its status according to its synchronous update with physical world;
- Self-scanning, self-prediction, and machine-based self-service [11].

3. CONCLUSION

Definitions and terms for DT, DS and DM are often used synonymously. Although there are differences between these terms, integration and cooperation between these concepts are necessary to create fully functional DT. Creation of DM with use of DS and connections between them allows to create DT. Concept of DT shows benefits in applications in whole lifecycle including manufacturing processes, production system, layout planning, production planning, products, services, maintenance, etc.

This paper was created with support of IPA 5/2019 project „Simulation of production processes with digital manufacturing tools”.

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Total cost of ownership, strategic cost management, industrial engineering

Miroslava BARBUŠOVÁ*, Iveta MEDVECKÁ**, Radovan SVITEK ***

APPLICATION OF THE TCO METHOD IN THE ASSESSMENT OF INVESTMENT VARIANT COSTS

Abstract
Supplier selection and evaluation are arguably one of the most critical functions for the success of an organization. One approach to objectively evaluate suppliers is total cost of ownership (TCO). TCO is a methodology and philosophy which looks beyond the price of a purchase to include many other purchase related costs. This approach has become increasingly important as organizations look for ways to better understand and manage their costs.

1. INTRODUCTION

A recent study indicates that purchased items make up an average 63,5% of total costs for manufacturing firms and 25% for non-manufacturers. Such expenditures are directly related to the organization´s costs, but many discussions of strategic cost management concepts focus primarily on control of manufacturing costs, such as labour and machine time. In most organizations, the costs of purchased materials and services far outweigh internal manufacturing costs. [1]
TCO is the sum of all the apparent and all hidden costs related to the asset over the total ownership period, over the total useful life and/or over the life of the asset. [4]
Total cost of ownership (TCO) is purchasing tool and philosophy aimed at understanding the relevant cost of buying a particular good or service from a particular supplier. References to TCO and related concepts, such a life cycle cost analysis, have been in the literature for some time, but its practical application has been somewhat limited. TCO is an important tool to support strategic cost management. It is a complex approach that requires the buying firm to determine which costs it considers most relevant or significant in the acquisition, possession, use, and subsequent disposition of a good service. In addition to the price paid for the item, TCO may include the costs incurred by purchasing for order placement, research and qualification of suppliers, transportation, receiving, inspection, rejection, storage and disposal. One use of TCO

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analysis is to support the supplier selection and evaluation decision. Traditional approaches include selecting and retaining a supplier based on price alone, or based primarily on price, or qualitatively evaluating the supplier´s performance using categorical or weighted point/matrix approaches. While the latter are preferred to a "price only" focus, such approaches tend to deemphasize the costs associated with all aspects of supplier´s performance and generally disregard internal costs. Examination of such costs is strength of the TCO approach. TCO is applicable to virtually every type of purchase and includes the purchase costs associated with particular supplier. [1,2]

2. TCO IS STRATEGIC COST MANAGEMENT

It can be argued that TCO is only truly strategic cost management when occurs on a strategic level, as in helping to improve the processes in the organization or the supply chain. In order for TCO analysis to quality as strategic cost management, cost considerations must span the boundaries of the organization to include costs both external and internal to the organization. By definition, all applications of TCO analysis do this by specifically considering the effects of the supplier´s performance, and the performance of purchased goods or services, on the organization´s total costs. [2,5] Unlike traditional cost reduction and cost saving techniques, which focus internally all TCO analysis is supportive of strategic cost management. That is because all TCO analysis considers the board effect of purchase decisions on the organization´s costs, as well as the implications of purchase decisions on other cost parameters. The relationship between TCO analysis and strategic cost management is depicted in Fig. 1. [2,3]

Fig. 1 Relationship between Strategic cost management and TCO

3. THE USE OF TCO FOR SELECTING NEW EQUIPMENT

When buying new equipment, the price reflects one small part of a big whole. Some sources say that the amount on the price tag represents less than 10 percent of the total cost spent on a piece of equipment over its lifetime. In fact, energy costs, maintenance, and repair fees are predicted to have at least five times more relevance than the upfront cost. But, few consider these factors as part of the price during their selection process. [3]

TCO must be used for full evaluation, which is an estimate of all collective expenses associated with the purchasing and operating a piece of the equipment. On the Fig 2 is seen total cost of ownership formula, where is:

I – initial cost – is the number that appears on the price tag. As previously stated, this is less than 10% of TCO.

O – operation – is the cost to install equipment, test the equipment, train employees to run the equipment, and the cost of energy to operate the equipment. If the equipment is complicated to use, the cost of training will increase.
M – maintenance – includes the cost of regular repairs such as cleaning, inspecting, lubricating, and adjusting the equipment to make sure it is in optimal condition. This also includes reactive maintenance when the equipment breaks down unexpectedly.
D – downtime – involves the labour costs of employees whose work is delayed, indirect labour costs from supervisors who address the issue, lost production, and lost customers from inability to meet time expectations. While you could include downtime along with the cost of maintenance, it is often so large that it warrants its own category.
P – production – Two different equipment will likely have different levels of output, produce different qualities and have different environmental implications.
R – remaining value – has to do with the equipment´s longevity. [3]

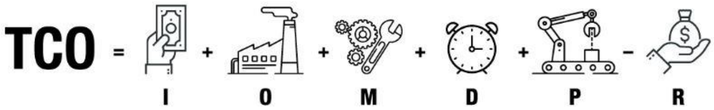

Fig. 2 Total Cost of Ownership Formula

For example, we will start with three variables to compare two hypothetical equipment: E1 and E2. The variables chosen are initial cost (I), maintenance cost over 5 years (M) and the remaining value after 5 years of depreciation (R).

Tab. 1 Calculation TCO for two equipments

	Equipment 1 (**E1**)	Equipment 2 (**E2**)
Initial cost (**I**)	10,000€	20,000€
+ Maintenance (**M**)	5,000€	2,000€
- Remaining value (**R**)	2,000€	10,000€
= TCO	13,000€	12,000€

TCO of E2 is less than E1 even though its initial cost was twice as much. However, the gap is only 1,000€, which is a slight difference (Tab. 1).
Now we add a fourth variable, estimated downtime. We will go with estimate and of 50,000€ per hour, even though downtime will likely be o lot more.

Tab. 2 Calculation TCO for two equipments estimated downtime

	Equipment 1 (**E1**)	Equipment 2 (**E2**)
Initial cost (**I**)	10,000€	20,000€
+ Maintenance (**M**)	5,000€	2,000€

Tab. 2 Calculation TCO for two equipments estimated downtime (continue)

	Equipment 1 (**E1**)	Equipment 2 (**E2**)
+ Downtime (**D**)	(3 hours at 50,000€/hour) 150,000€	(1 hour) 50,000€
- Remaining value (**R**)	2,000€	10,000€
= TCO	163,000€	62,000€

Equipment B costs 101,000€ less than equipment A (tab.2). The price gap becomes wider with every variable that you add, giving you a clear choice for cost value.

5. CONCLUSION

The Total Cost of Ownership approach is widely adopted in business-to-business contexts from both the academic and practitioner communities. However, it has still received little an attention in business-to-customer settings. This paper aims to fill this gap. In particular, it adopts the stand point of the private customer and develops a general model for assessment of the TCO of a durable consumer good.
The TCO calculation in the article points out that the price on the price tag is not the only cost of operating the equipment. It can be seen that although the cost is 2 times lower on one equipment, the total cost of the one may not be lower. It is also necessary to look at the hidden costs associated with the purchase, installation and use of equipment.

This article was created with support of project: KEGA 022ŽU-4/2018

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Industrial engineering, DIERS, Occupational diseases, Raster Stereography

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DIERS SYSTEM AS A NON-RADIATIVE WAY TO DIAGNOSE THE SPINE

Abstract

Damage to the musculoskeletal system is a current problem that is solved in every production and non-production sphere. At present, the most difficult part of the human body is just the spine, but so far the disease is not categorized as an occupational disease. . The article is a brief overview of the backbone load caused by work activities. It describes a device by which it is possible to correctly identify characteristic activities that can lead to work-related spinal disease.

1. OCCUPATIONAL DISEASES

Occupational diseases are diseases that arise in a causal relationship with the work performed due to the adverse effects of the chemical, physical, biological and other risk factors of the working environment. In 2017, 354 cases of occupational diseases and professional poisonings were reported in the Slovak Republic. Compared to 2016, the number of reported diseases increased by 38 cases in 2017. The most stressed part of the human body is the spine. Musculoskeletal and connective tissue disorders are increasing in character. In 2014, 83,273 diseases were recorded. In 2017, it was up to 93,338 musculoskeletal and connective tissue diseases. [1]

1.1. Load of the spin due to work activities

Nowadays, work activities characterized by frequent repetition of the same work movements with demands for high movement coordination enter the forefront. In many cases, workers must perform their work for a long time at a forced pace and also with excessive static and one-sided loads on not only the limbs but also the spine. This disease contributes significantly to reducing the quality of life of workers. It is therefore necessary to address the problems of occupational diseases [2,3]. To do this,

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it is important to know precisely the factors that initiate the disease and monitor the course of the disease. This information could be identify by a suitable predictive system. The creation of such a system would be precede by monitoring the degenerative processes of the spine, due to the onset of disease manifestations and subsequent identification of factors that may cause the problem. Sometimes it is very difficult to indicate whether the spine difficulties are really labor-related or a dominant factor outside the working environment. With using raster stereography and a device working on this principle, it is possible to identify those characteristic activities that can lead to the creation of a conditional illness. [4]

2. RASTER STEREOGRAPHY

Drerup and Hierholser developed surface topography, known as a raster stereography, in 1980. This radiation-free technology projects horizontal light strips on the back of the patient's body. Subsequently, the still images of these lanes are recorded and digitalized. Due to the deformation of the projected horizontal lines, a three-dimensional image of the body surface can be create. For each scan, the device calculates 40 body shape parameters based on angles, spacing, and spinal and pelvic variations. Based on the individual parameters, the algorithm calculates the average values from the entire scan, selects the nearest image to the average values, and determines the parameter values for that particular image. The DIERS formetric system works on this principle. [5]

Fig.1 Raster stereography [5]

1.1. DIERS 4D Motion lab

A complete system called DIERS 4D motion ® Lab is a stationary examination device. This system allows you to view the spine and its segments when moving. The DIERS is a video-rasterographic device that was created in 2005. The device is equipped with a camera or a camera. Camera and software that allows you to track interactions between vertebrae and pelvis while walking and other movements. The device is used for diagnosing faulty posture, for evaluating spine flexibility, for various asymmetry in movement, and for evaluating the effect of therapy. Advanced equipment may be added to the base unit. The DIERS leg axis module, which is used to measure the axis of the legs and to walk analysis, and the DIERS pedogait model. [6]

Fig.2 DIERS 4D Motion lab [6]

1.1.1. DIERS Formetric 4D

This system is based on 4D technology (expanded 3D technology by time). The device allows performing functional tests and postural analysis. With 1 minute recording, the system can create up to 10 frames per second. In addition to functional analysis, it can obtain the average of data from the recording, thus achieving a higher accuracy needed for postural variations of the human body. [7]

1.1.2. DIERS leg axis

DIERS leg axis enables the geometric analysis of the lower limbs to be performed quickly and efficiently. It is another module for the DIERS 4D Motion Lab diagnostic complex, which allows video walking analysis and spine condition. The module is equipped with rear and side cameras for a more complete and visual analysis of the foot performed before and after foot correction. [8]

1.1.3. DIERS Pedogait

DIERS pedogait is a treadmill that incorporates a pressure plate that measures the pressure distribution on the foot during a walk. The system analyses the shape of the back, spine curve, and vertebral rotation, based on various anatomical and biomechanical models. . [8]

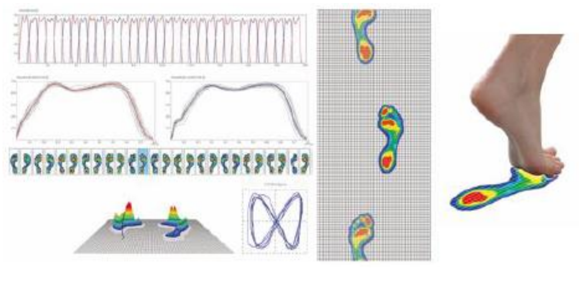

Fig.3 Pressure distribution on the foot during walking. [8]

3. CONCLUSION

Occupational Disease is a phenomenon that any natural person may encounter in the performance of his / her job. Problems and pain in the back area are the most common difficulties experienced by workers in relation to work. The spine exposed to a heavy load due to the incorrect positioning of the human center of gravity and in combination with excessive time exposure. The static load most often caused by standing or sitting work also causes muscle wasting, which is the most important support element for the spine. These factors manifested spinal deformity, which can lead to feelings of discomfort through pain to severe degenerative diseases. Such diseases will significantly reduce the quality of life and, of course, the ability to work. An important memento is the early indication of emerging physiological problems, by which preventive programs and rehabilitation can prevent the reduction of work performance. At the same time, it is possible to identify (if any) work activity that has a negative impact and is involved in the disease. Modern diagnostic tool DIERS 4D motion® Lab provides a convenient and safe way of screening without side effects on human health. It is a measurement technology without the use of radiation. The result of the examination is the overall diagnosis of the spine, which is currently the most loaded part of the human body. With using this technology, working on the principle of mathematical modeling, it will be possible to create a predictive system that will eliminate work-related diseases.

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-16-0488

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Measurement System Analysis, Production Engineering

Tomasz BOROWY* , Dariusz PLINTA**

MEASUREMENT SYSTEM ANALYSIS FOR VARIABLE DATA

Abstract
Measurement System Analysis (MSA) is part of a structured approach based on the Lean Six Sigma methodology and it is a requirement for manufacturers to apply it. The purpose of this article is to present a structured approach to MSA, which may be implemented in various industries. This method is presented using the MINITAB software that supports statistical analysis. The analyses are based on available data. In general, types of data can be classified as variable and attribute data. In relation to data types, appropriate indicators are used to qualify our measurement system.

1. INTRODUCTION

As quality requirements are constantly being increased by customers, the industry should improve its processes and measurement methods. According to the Lean Six Sigma approach, the collection and usage of variables such as force [N], length [m] are more useful and informative for production companies.

2. MSA ANALYSIS FOR QUANTITATIVE DATA

The main concept of MSA is based on accuracy and precision, as well as on the following terms:

- Resolution – scientific literature mentions the 1/10 rule, i.e. measurement devices should measure at least 1/10th of product tolerance or the proces variability [1]. According to the VDA 5 norm, the measurement device should have a resolution equal to or lower than 5% tolerance [2].
- Number of Distinct Categories (ndc) - number of separate groups of parts, which can be distinguished by a system. The number of distinct categories must be higher than or equal to 5.
- Bias - a measure of the measurement system inaccuracy; the difference between the observed average measurement and the real value [1,3].
- Stability – it determines how well the system performs at a given time.

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- Linearity - the change in bias across the range of a device.
- Repeatability - how much variation appears when the same worker measures the same part repeatedly with the same device. It is the variation due to a measuring device.
- Reproducibility – it determines how many variations appear when different workers measure the same part using the same device. It is the variation due to a measuring system [1].

Tab. 1. MSA indicators for acceptance of the measurement system.

Categories, tools	**Acceptance criteria**	**Recommended number of repetitions**
Resolution	1/10÷1/20 tolerance or proces variation	-
Adequate Resolution, Gage R&R	ndc > 5, recommended >10	≥30, recommended **90** (2÷**3** operators, 5÷**10** parts, 2÷**3** replications)
Bias, Type I Gage Study	Cg, Cgk >1,33	recommended 50, min. 25,
Stability, $\overline{X}$ - R chart	Lack of special causes	≥100
Linearity, Gage Linearity and Bias Study	p-Value >0,05	≥30
Repeatability, Reproducibility, Gage R&R	ndc > 5, recommended >10, % Study Var, % Tolerance: <30% recommended <10%	≥30, recommended **90** (2÷**3** operators, 5÷**10** parts, 2÷**3** replications)

When analyzing a measurement system, first the resolution should be checked. Then we should verify bias by repeating measurement of the same part. That part should be oriented in the same way. An evaluation is based on t-test and p-Value.
If our measurement system works in different ranges, we should verify linearity. In Gage Linearity and Bias Study, we draw conclusions on the basis of p-Value.
Next, we perform Gage R&R analysis. We should remember that poor Gage R&R deteriorate our Cp indicator [4]. Samples should be taken from the whole tolerance range and contain inconsistent parts near the tolerance border. Every sample should be marked and randomized. The measurement procedure should be controlled. After the analysis, we check the ndc indicator and inference base on the percent of study variation and percent of tolerance. Also, we should assess our system on the base of a graphic analysis. Testing of stability is recommended. A part, or a master part should be prepared in the middle of the tolerance range (sometimes also for the bordered dimension). The test should be carried out periodically and the result should be put into a $\overline{X}$ - R chart.
All indicators and acceptance criteria are mentioned in the table above.

3. AN EXAMPLE OF MSA FOR SHAFT DIAMETER MEASUREMENT

In a plant which produces metal parts, one of the products is a steel shaft. The diameter of this shaft is 12.305 mm and tolerance is ±0,05mm. Due to a quality problem, a quality engineer along with his team conducted a MSA analysis using the MINITAB 16 software.
Initially, the Type 1 Gage Study was performed, however the result was not acceptable (Cg, Cgk<1,33). The team conducted an analysis and found out that the problem was related to a measurement bench and a method of fixing parts. After introducing a new method, the team performed the analysis again and achieved acceptable results.

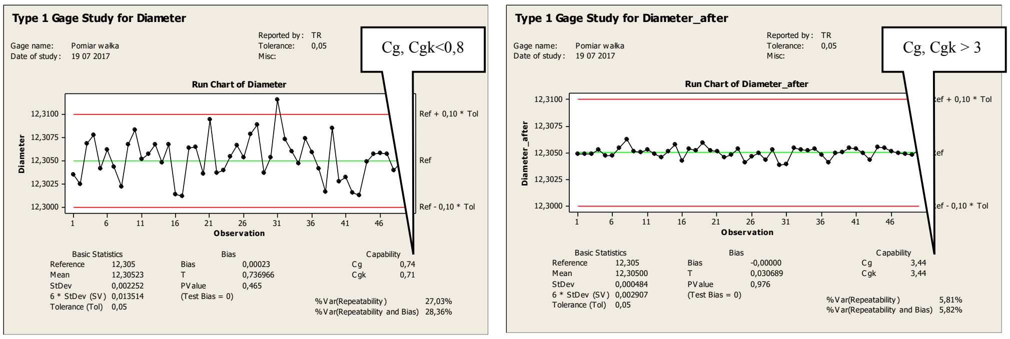

Fig.1. Type 1 Gage Study – before and after improvement.

The team continued the analysis and performed *Gage R&R* for checking the influence of a human factor on results. After the analysis, the result was not acceptable (ndc =4, % of Study Variation, % of Tolerance >30%). It was recommended to train the first operator. Another recommendation was to perform the Linearity and Bias Study. The analysis identified that the problem was related to linearity and too high bias in extreme value, which might explain discrepancies in the performance of the first operator. It was suggested to change the angle of the read off and repeat the analyses.

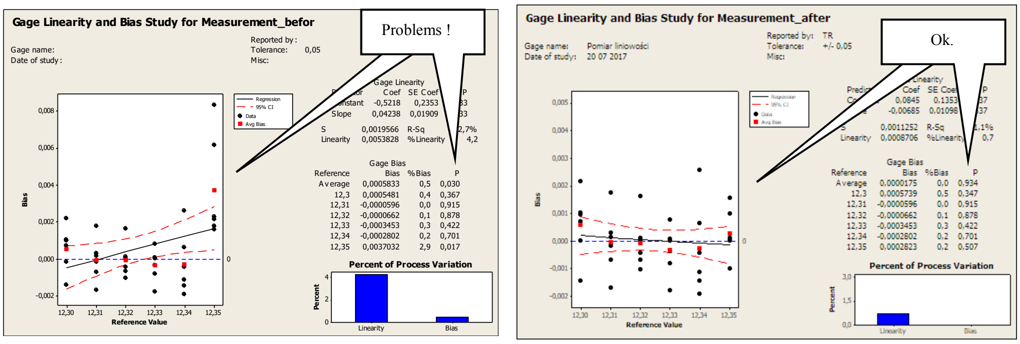

Fig.2.Gage Linearity and Bias Study before and after

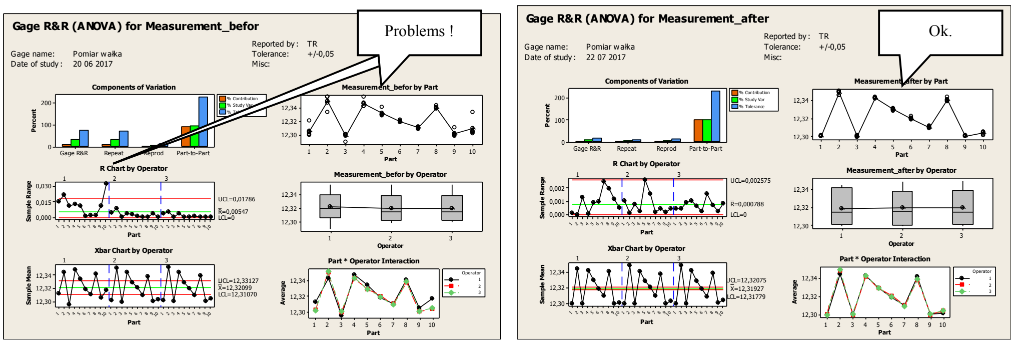

Fig.3. *Gage R&R* Study before and after

The recommendation was effective. After performing the new analysis, the results were acceptable - no problem with Bias or Linearity p-Values (>0,05) and indicators such as ndc and % of Study Variation, % of Tolerance were improved (ndc=20, % Study Var = 6,93, % Tolerance=15,92).

Finally, a test of stability was performed using the *Xbar-R* chart. After collecting 25 subgroups with 5 measurement each, no special causes were identified, which means no issues with stability.

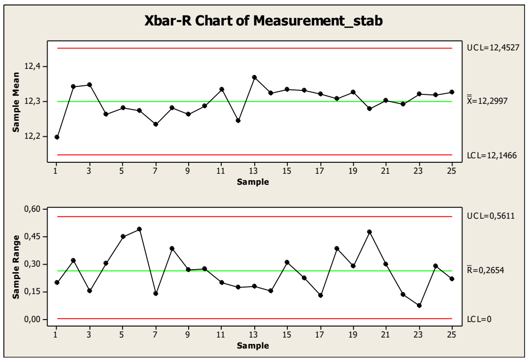

Fig. 4. Xbar-R chart – no problem with Stability

4. CONCLUSION

The approach for MSA described above is consistent with the Six Sigma methodology and A.I.A.G. requirements. The approach of VDA 5 norm is different, because it divides a procedure into two phases: before production and during production, as well as contains precise procedures to examine the uncertainty of measurement. It is recommended to know client expectations and check if the system is appropriate for each customer.

We should remember that verifying the measurement system by the described procedures according to standards and procedures should be realized in a consistent way by all operators. It is also recommended to check the following aspects: calibration, accuracy or precision of measurement devices and sample size.

If we want to improve our measurement system or look for causes of variability, we may use the P.I.S.M.O.E.A model, which is focused on the following elements: a part, a device, a norm, a method, an operator, an environment and an assumption. The analysis has shown that problems with a measurement system may occur in different places and the structured approach allows to recognize all kinds of variability.

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Computer Simulation, Energy Consumption, Industrial Engineering

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COMPUTER SIMULATION OF ENERGY CONSUMPTION

Abstract
This article provides basic information about using computer simulation with the goal of simulating energy consumption of production or equipment. In the core of article are described basic information about simulating of energy consumption. This article gives to reader answers on the question of how simulating of energy consumptions can help companies to increase their productivity and efficiency.

1. INTRODUCTION

Simulation is evolving very quickly for several years by the development of technologies and software solutions. Its use expanding from production, logistics, warehouse processes, workforce also to monitoring of energy impacts of production. Each model is created by gradual input of real process parameters such as operational inputs, process flow or resource use [5]. Process simulation allows to collect and analyse data, experiment with it, without interrupting of production or logistics processes. Simulation of energy systems or the use of energies to ensure the running of an industrial enterprise is always done with the goal of analysing large amounts of data [7]. Computer simulation of energy systems is another step in the analysis of these systems. It offers the possibility of analysing different production or logistics scenarios, while each brings different energy use scenarios.

2. COMPUTER SIMULATION OF ENERGY CONSUMPTION

The described development of technologies enables to extend also the methodology of the simulation model creation by another step, by energetic evaluation of operation

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by the simulation software (Fig.1). The first step in creating a simulation model is to name and describe the problem what is necessary to solve with this tool. Only then it is possible to do a step of constructing a real-system simulation model and its setting (machines, warehouses, handling units, etc.), time constraints, safety constraints, system constraints, and other settings. After the first simulation runs, experiments are conducted with the simulation model to produce results that need to be correctly interpreted and used to improve the system. Only after these steps, when the validation and verification of the model confirmed its accuracy, it is possible to start statistically evaluating the energy evaluation of the operation. After these steps, there should be no significant changes in the model that would affect the statistical evaluations.

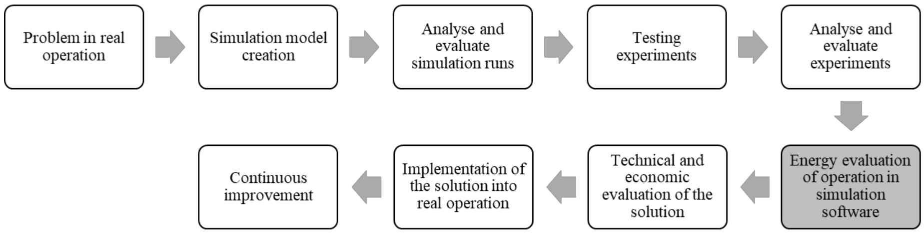

Fig.1. A shortened process of creating a simulation model

The main elements on which consumption of different types of energy can be measured are machines, containers, conveyors, robots. The software tool that is used by the Department of Industrial Engineering, Tecnomatix Plant Simulation, provides a statistical tool for energy consumption assessment called Energy Analyzer. This tool is patented by SIEMENS (U.S. Patent App'l Pub. No. 2013/001863) [1]. The following illustrated examples were also created at the Department of Industrial Engineering.

2.1 Energy evaluation of production

A significant part of the electricity consumption is in production mainly in machinery and equipment. But after the development of simulation software, it is possible to include here lighting, ventilation, cooling or system failures also. Even though these indicators may not have a significant impact on production, they may trigger other problems that may stop the smooth running of production. The basic energy consumption indicators for machines or equipment that we can evaluate with Tecnomatix Plant Simulation include [kW]:

- Total energy consumption indicator,
- energy consumption of operation,
- total energy consumption of any kind of object while it was working,
- power consumption during the setting of the object,
- operating energy consumption,
- energy consumption at the time of machine or equipment failure,
- the total power consumption of any kind of object in standby mode,
- the energy consumed when the object was turned off, etc.

Accurate statistical evaluation of these indicators during production or logistics simulation will bring benefits such as:

- Reducing the cost of consuming different types of energy,

- maximal use of production or logistics resources,
- improving material flows,
- reduction of investments in the purchase of new machinery or equipment,
- increasing the productivity of existing machines or equipment,
- reduction of machine and equipment failure rates,
- accurate statistical evaluations of the consumption of different types of energy,
- from the perspective of creating and using simulation software, it is an open system architecture,
- supports interfaces and integration capabilities (ActiveX, CAD, Oracle SQL, etc.),
- detection and reduction of bottlenecks in manufacturing or logistics, etc.

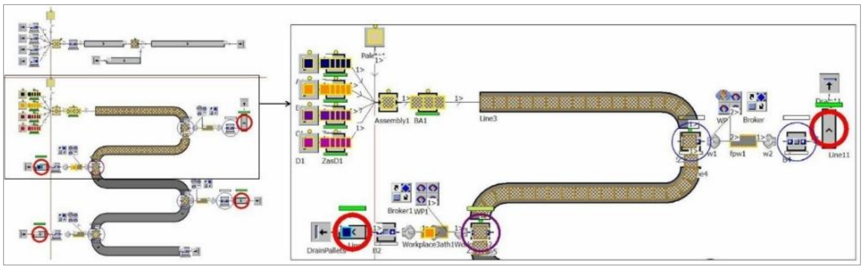

Fig.2. The sample of 2D simulation model of energetic evaluation

Figure 2 shows the 2D and 3D views of simulation using Tecnomatix Plant Simulation. It is possible to see in the rings the display of the machines on which the energy consumption is measured [1]. The highest power consumption is displayed in a wide red circle, lowest by blue circles.

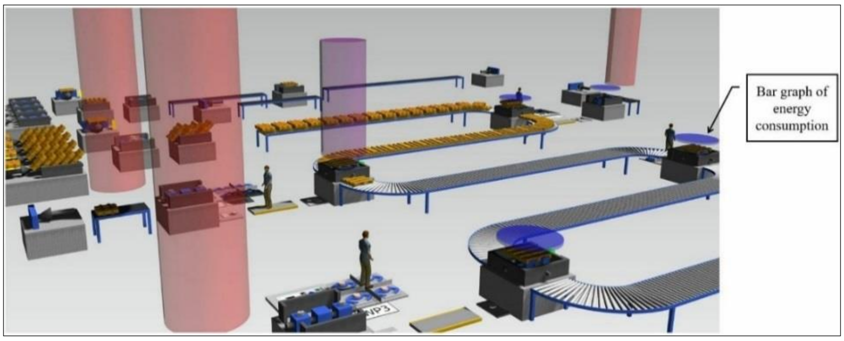

Fig.3. The sample of 2D simulation model of energetic evaluation

In the 3D view, on the figure3, graphical visualization is represented by bar graphs of any colour. This image brings innumerable benefits, especially clear and accurate display of energy pumping by machines, conveyors and other devices [2]. Energy Analyzer as a patented Simulation Energy Measurement Tool, developed by Siemens, provides energy status data. Displaying results after simulation runs gives information about total electricity consumed in a given production cell or in a production hall. Directly during the simulation, it measures within the set time frame how much energy was consumed during operation (Fig.2., Fig.3.). High utilization of computer simulation will make it possible to monitor the energy delivery-chain systems, reduce the energy consumption, and prevent the failures of energy systems and blackout of the power systems.

3. CONCLUSION

Energy consumption monitoring can be used to reduce energy consumption based on simulation runs. Software products have built-in solutions whose proper use will bring benefits and new solutions to all levels of the business [3]. The productivity of workplaces or factories will increase, with economic results clearly improving [6]. The simulation becomes a strong support tool for the forthcoming 4th Industrial Revolution, called Industry 4.0. After periods of use of first manufacturing machines, mass production, and integrated PLC systems, there comes a time of smart factories and manufacturing, in which modern technology will play a primary role [4]. Energy consumption and management are essential aspects of this kind of production and planning. Using various software solutions, accurate analyses of the current state of workplaces are made, as well as new production cells to achieve the lowest possible electricity consumption and thus contribute to overall production higher efficiency. As a result of using the digital factory tools are clearly contributing to the improvement of business and production processes and will become an essential part of any engineering company philosophy.

This article was created with support of project: KEGA 017ŽU-4/2019

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Smart Industry, Trends, Industrial Engineering

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SMART INDUSTRY TRENDS

Abstract
This main goal of this article is bringing to reader basic information about the development of smart industries and smart manufacturing. In the core section is described impact of trends. The first part of the core is about the impact of trends on the operation of production. The second part is dedicated to trends that will form nowadays industries into smart industries and manufacturing.

1. INTRODUCTION

Digital transformation continues increasingly more intensely across all sectors. The advent of new technologies is manifested mainly in logistics and manufacturing due to the overall benefits they bring to businesses in terms of productivity, quality and process flexibility [1]. That's why companies are now investing heavily in Smart Industry solutions. Digital Twin, Artificial Intelligence, Industrial Internet of Things as well as Warehouse Robotics are key Smart Industry trends and elements in logistics and manufacturing not only in terms of industrial transformation but also in terms of continuous improvement.

2. SMART INDUSTRY

SMART means more efficient, flexible and environmentally friendly factories and workplaces. With conjunction of word SMART and revolution is it possible to talk when the factories and workplaces work is fundamentally changed. Various technological advances that have occurred in recent decades are conjunction with words SMART and evolution. Industrial infrastructure is therefore mainly developed in three ways:

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- **Efficiency** - Higher efficiency can be improved at all points in power usage with a particular focus on power conversion & energy harvesting, power management, power storage and motor control, etc.
- **More intelligent and aware**
    - o Sensors collect information about every machine all the time.
    - o Machines are aware of the humans around them and provide new interfaces such as smart tools, augmented reality and touchless interfaces for easier and safer interactions.
    - o Safe & secure distributed local processing allows data to be turned into information, allowing real-time monitoring and predictive maintenance and repair.
- **More Connected**
    - o Machines are connected inside the factory to the larger supply chain and to the cloud. When orders can be customized in real time and only what is needed is actually made, this enables optimal planning and flexibility in manufacturing.
    - o Real-time communication down to the lowest level of sensors and actuators, ensuring optimal reactivity and real-time analysis processes, etc.

Technology development will help to obtain huge amounts of data that can be evaluated, processed, sorted and used for further development and research. Industry 4.0 technologies give greater knowledge of the manufacturing process, supply chains, distribution chains, business performance, and even the products that are manufactured [6]. This creates opportunities to innovate, whether that is changing a business process, developing a new product, optimizing a supply chain, improving OEE, and more.

Production lines will also experience less downtime because of enhanced machine monitoring and automated/semi-automated decision-making. In fact, general OEE (Overall Equipment Effectiveness) will improve as the facility moves closer to becoming an Industry 4.0 Smart Factory. Among the trends that will shape the direction of both industrial engineering and industry 4.0 are:

- **Digital Twin** - In the case of cyber-physical systems (CPS), the digital twin functionality is extended as it allows a physical object to interact not only in virtual but also in real space. This creates an active digital twin or virtual intelligent agent of a physical object. This kind of digital twin finds its application in Smart Industry systems and solutions, where it serves for the operational planning, management and monitoring of production and logistics processes or selected supply chain components [5]. In a world where virtualization and social networks have become a part of everyday life, we can already see the advent of various software bots, automated services and autonomous customer service based on digital twin principles.
- **Cognitive technologies -** Cognitive technologies include mainly machine learning (ML), speech recognition, natural language processing, spatial orientation and computer vision. These technologies will be implemented for comprehensive supply chain management and in-house processes, especially in supply management - warehouse process management and production logistics (intralogistics). The aim of the implementation projects will be, above all, to ensure the highest possible efficiency of logistics and industrial processes, to achieve a higher quality level and to ensure the flexibility of processes due to the growing demands of clients and the market [3].
- **Robotization of Warehouses** - Given the above-mentioned trends in the development of cognitive technologies and increasing the "intelligence" of individual equipment, is it possible to expect more intensive warehouse robotics and supply management.

In addition to the more extensive deployment of AGV and semi-intelligent AGVs with the introduction of IGV and autonomous warehouse robots (AWR), there will also be a wider deployment of picking robots [8]. These operations will provide facilities that combine autonomous orientation and movement in space with the ability to manipulate objects (grip, pick up, store). The new generation of devices will be geared towards the type of humanoid-type robots or cobots that will naturally collaborate with human workers. Drones with a built-in barcode reader or RFID scanner, which are adapted to move in a closed space, are already available today.

- **Intelligent Warehouse Management System** - The next stage is ensuring the interconnectivity of all objects in the warehouse by means of the implementation of internet of things (IoT) technology. Operative management of warehouse processes comes into play at this level by way of either the predefined rules or autonomous algorithms. Materials/products are not moved anymore according to a static regulation in the warehouse; algorithms of a warehouse management system, on the other hand, evaluate the demands in real time and based on a complex set of criteria, such as current occupancy of storage positions, the degree of turn-over, or seasonality.
  The relevant data are then gauged considering the current conditions and previous development of selected indicators that point to factors which enable dynamic management of storage and picking processes. Concerning operative management, this solution offers the operating personnel wider features of visualization as the personnel is precisely and in detail navigated by the information system in performing tasks.
- **Seamless Human-Machine Interfaces (HMI)** - With the increasing digitization and horizontal and vertical integration of logistics processes, it will be crucial to facilitate the communication of workers with implemented controller systems (ERP, WMS, APS, MES, MOM, ALM, PLM) and Smart Industry systems. Already today, in some businesses, a proximity interface is used to control systems by capturing gestures or voice control. Natural language processing technology allows, for example, immediate two-way communication between warehouse workers and the warehouse management system application module (WMS system) [3].
- **Cybersecurity** - Creating robust infrastructures and distributed architectures, expanding the internal Internet of things beyond the physical space of the business, and exponentially increasing data volumes, will require more comprehensive cybersecurity solutions. Increased attention will also have to be paid to data protection in databases and data storage, data leakage prevention and Data Leakage Prevention (DLP). Strengthened next-generation firewalls against distributed-denial-of-service attacks and hacker attacks, as well as protecting the industrial environment from external interference or targeted or unintentional sabotage from the company's internal environment, are essential. [3]
- **Advanced Analytics** - With digital transformation, the number of sensors is increasing in businesses, causing an exponential increase in available data. The current approach to Business Intelligence (BI) will no longer be sufficient to extract key information and knowledge from the mass of diverse data.
  Artificial intelligence will therefore not only assist in sorting and preparing data, metadata and so-called dark data, but also their processing. Such a form of expanded analytics will make it possible to extract relevant information such as behavioural patterns and correlation patterns, or various forecasts, predictions, and recommendations.

3. CONCLUSION

Smart manufacturing has pervaded across multiple industries and is projected to overhaul the business landscape in the years to come. Smart manufacturing refers to the use of computerized systems and key manufacturing technologies in order to enhance the agility, quality, and speed of manufacturing [7]. The international industries for smart manufacturing is anticipated to be bolstered by the demand for a range of technologies, including human machine interface (HMI), machine vision, distributed control system (DCS), enterprise resource planning (ERP), programmable logic controller (PLC), supervisory controller and data acquisition (SCADA), and manufacturing execution system (MES) [2].Currently, manufacturing and distribution companies face challenges such as improving performance, quality and ensuring the agility of their own processes and thereby achieving intelligent logistics management.
Smart Industry's modularity enables businesses to scale automatization and digitalization processes in stages, in a decentralized manner, taking into account the priorities, central strategy and challenges facing or facing the business. The Internet of Things, combined with material identification and tagging, makes it possible to collect large amounts of data. Data analysis of these data then helps workers to make qualified decisions. Traditional logistics systems are being gradually replaced by dynamic systems designed in accordance with the principles of lean management and allow autonomous coordination and synchronization of in-house supply with production processes [4].

This article was created with support of project: KEGA 017ŽU-4/2019

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Target Costing, CAD software, unit production

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ANALYSIS OF PROFUCTION TECHNOLOGY FROM THE POINT OF VIEW OF COST

Abstract
The reduction of production costs is important from the technological point of view. The purpose of this work is to explore the role of cost accounting target as a part of the evaluation of Productibility Design. An example was produced as component part of the product-conveyor belt produced in the process of design to order (production unit).

1. THE IMPLEMENTATION OF A NEW PRODUCT

The process of deploying new product is complex, routed in a pre-specified time and consisting of many phases and stages. Depending on type and complexity of the products, the seriality of production, preparation of technical solutions used are different methods and techniques of project management, preparation and implementation of new technologies and products to the manufacturing practice.

1.1 Concept of Target Costing

Target Costing is the method used in the management of costs in order to obtain the maximum reduction of costs of production throughout the life cycle of the entire product. This account focuses mainly on phases related to preparation of new item production. When the production started the most important are actions to minimize costs through continuous improvement running production. (Kaizen Costing) [1].
The concept of Target Costing was first used by Toyota in the 50s 20th century. Financial pressure and the desire of shortening production cycles has a major impact on costs during the planning phase of the deployment process. Other factors affecting the development of Target grew the competition and the quality requirements of implementation process rapidly. Target Costing is a base that must be considered while applying a new product. Thanks to Target Costing the product placed to market is characterized by desired quality, price and functionality with the expected profit.

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2. ANALYSIS OF THE TARGET COST FOR A SELECTED ELEMENT OF THE CONVEYOR BELT

To properly analyze the cost of project target the product must be selected in a detailed. In further consideration there will be carried out an overview of variants of the production process for the main element of the drive station of conveyor belt. There will be presented five alternative routes of implementation the following element (fig. 1).
The target cost of production depends on prices proposed by the client and the expected profit. Assuming that the company conducts natural profit-maximizing policy, at constant price offered by the market, it must minimize the cost target production from the earliest phases of product development, especially in the design process. In this situation, the task of the proposed method is to find the design variant with the lower cost of production.

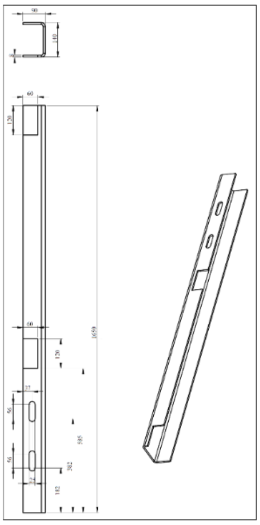

Fig. 1 Basic element of the frame conveyor belt

Enterprise access to CNC machines such as milling machines, laser cutting machine, cutting machine and CNC bending machine this item you can perform five alternative routes:

- Method 1
    - the purchase of material (C- section),
    - use the milling machine to make a holes,
- Method 2
    - use the laser cutting to make sheet template (for bending) - cutting together with the holes,
    - use bending machine to make c-section element,
- Method 3
    - use the guillotine machine to make sheet template (without the holes),
    - use bending machine to make c-section element,
    - use milling machine to make holes,

- Method 4
  - use guillotine to make 3 sheet metal,
  - use milling machine to make holes,
  - weld sheet metal the shape of the C-section,
- Method 5
  - use the laser cutting to make 3 sheet metal (with holes),
  - weld sheet metal the shape of the C-section.

2.1. Cost module in SolidWorks software

When carrying out calculations on the cost of production uses the module "costing" in the SolidWorks software. This tool is useful for constructors in decision making when choosing a technology element from the point of view of the cost of production, as well as allow the manufacturer to determine the final price for a specific group-recipients (customers). When you change data of the cost implementation cost of the item and its detailed distribution is performed automatically.

Module "Costing" uses data about manufacturing and materials, which are placed in the templates. In the templates, you can specify parameters such as:

• the material element,
• the manufacturing process (e.g., milling, bending or laser cutting),
• production method (3D printing, casting, machining),
• the cost of the material,
• cost of production for each of the methods for the seriality of production.

In addition, the templates, you can create custom operations for example. painting, cleaning and packing.

2.2. Comparison of the production cost

The following image shows the steps for the implementation of the element.

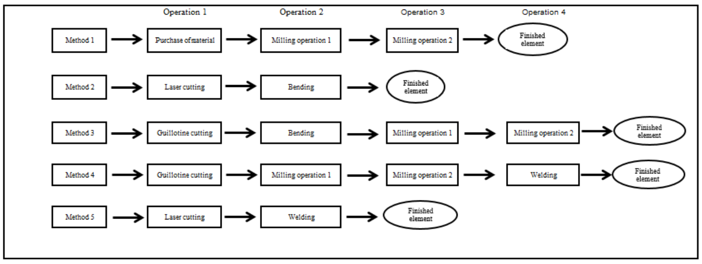

Fig. 2. Methods to obtain element

Below there is the table which shows comparison of production costs of element.

	Method 1	Method 2	Method 3	Method 4	Method 5
Material	122,00 PLN	70,15 PLN	70,15 PLN	70,15 PLN	70,15 PLN
Operation 1	180,00 PLN	33,15 PLN	24,00 PLN	32,00 PLN	61,20 PLN
Operation 2	115,00 PLN	84,00 PLN	84,00 PLN	130,00 PLN	184,00 PLN
Operation 3	X	X	180,00 PLN	90,00 PLN	X
Operation 4	X	X	115,00 PLN	184,00 zł	X
SUM	417,00 PLN	187,30 PLN	473,15 PLN	506,15 PLN	315,35 PLN

The calculated costs are based on the prices of materials and services offered by the companies in the production of this type of elements.

3. CONCLUSION

By analyzing the values of parameters evaluation of Producibility design, it can be concluded that:

- assessment of the values of the parameters of the process and the costs can be the basis for structural design, product manufacturability analysis
- assessment should take into account many other factors relating to the sale, service, availability of spare parts, the serialized option generation, types of equipment, available mounting techniques, automation level, cooperative services, opportunities use of commercial components, technical culture crew etc.

In terms of domestic industry of great importance in the process of executing the production is the process of cooperation, hence a significant attention in the design and implementation of new products is committed to the issues of improving their manufacturing from the point of view of: supply, cooperation as well.

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Warehouse management, storing processes improvement

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SUPPORTING TOOLS FOR WAREHOUSE PROCESSES

Abstract
This paper describes selected issues related to warehouse processes. In general, the article characterizes requirements regarding warehouses and tools facilitating delivery, materials storage and distribution, as well as their completion and dispatch from warehouses. The following part deals with the assumptions in relation to warehouse design, including the ABC analysis method, and features a practical example of a door manufacturing company.

1. INTRODUCTION

Contemporary development of production processes leads to increasingly complex transport and storage of materials. As a result, it is very important to design a warehouse properly, according to the dimensions, quantity and weight of the components to be stored. Nowadays, warehouses should be designed to facilitate faster manipulation of stored materials. To design a new warehouse, first of all we should analyze:

- what will be stored,
- how many materials will be stored,
- the influence of external factors is, e.g. atmospheric factors,
- which means of transport will be used, e.g. trucks, forklifts, handcarts, etc.,
- whether we will need gantry and ramps,
- the size of the stored materials - handy trucks will be enough for smaller materials,
- how the data exchange system will work – for example, using barcodes or RFID technology (in order to minimize the registration of delivery time).

When a new warehouse is designed or an existing one is reorganized, special attention should be paid to the new technologies, which can be used there.

2. NEW TECHNOLOGIES IN WAREHOUSE MANAGEMENT

One of the most important and constantly developed technologies supporting inventory management are automatic identification systems, which include solutions based on barcodes and more often on radio signals (RFID).

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A barcode (Barcode) is a combination of light and dark elements of various sizes. While reading the code by a special reader, the light is reflected by the bright elements of the code (gaps) and absorbed by its dark elements (lines, fields) [1, 2].
RFID (Radio Frequency Identification) is identification with the use of radio frequency. RFID systems use radio waves and electronic circuits for transferring data. Such a system consists of a reader, which contains a transmitter, a receiver, a decoder and transceiver antennas. Transmitters, called RFID tags, are divided into active, semi-passive and passive tags. An active tag consists of a data carrier, an antenna and a power source which absorbs energy to transmit a signal. A semi-passive tag has a power source for the data carrier and the power of the transmitter comes from electromagnetic induction generated by the radio waves that are transmitted by the receiver. A passive tag has no power source. Data information and the signal are supplied by electromagnetic induction which is transmitted from the receiver [1, 2].

Table 1. Comparison of a barcode and a RFID code [3]

	Barcode	RFID
Reading speed	Manual reading of each item, each barcode	You can scan about 100 items at the same time
Eye contact	The user must aim the reader at the bar code	It does not require eye contact
Human involvement	An operator must read each bar code separately	You do not need more employee involvement
Possibility of control	There is no possibility of control	Great controllability, e.g. processes, alarms, etc.
Ability to save	It does not have the ability to write	Possible record of information, e.g. product release date, inventory, etc.
Strength	Low, very easy to destroy, poorly resistant to seizure or water	High durability, can work in unfavorable conditions
Security	Zero, any unwanted person can read the code	Large, data can be encrypted with a password

In order to save time and due to economic factors, RFID is more and more often used to mark goods in production warehouses. Depending on different types of coding for different materials, it can be used at various stages of production, e.g. when a product is ready and has to be transported to the appropriate warehouse. Therefore, registration of such products usually takes place by the RFID stationary gateways which allow for automatic collection of logistic data. In order to save time and ensure faster handling, especially in case of heavy materials, **industrial robots** are more often being used in warehouses as another useful technological solution, as they can almost fully replace human work. A person only supervises such devices [4]. Another tool supporting warehouse processes are computer systems - ERP (Enterprise Resource Planning) and WMS (Warehouse Management System). The former mainly supports resource planning of an enterprise by the use of a common database for this purpose. In a one system, the entire company uses only one set of data. The latter is dedicated to support warehouse management, but it also can be integrated with the ERP system.

3. CLASSIC METHODS OF INVENTORY LEVEL ANALYSIS

In addition to the technologies mentioned above, classical methods of analysis, such as the ABC / XYZ method, are still very important and form the basis for improvements [5]. The ABC method is very often associated with warehouse management. It allows to effectively manage and control stocks, which have been located in individual places in the production hall and to pay attention to the frequency of product movement. As the name suggests, products are located according to the alphabet, so the A category products deserve the greatest attention and should be placed closest to the point of use.

The ABC method is developed into the ABC/XYZ method. The X group is the group which requires regular demand. Parts in this group will require accurate planning and timeliness of delivery. The Y group is characterized by the seasonal demand. For example, during the holiday season in favorable weather conditions, frequency of ordering doors is higher as positive temperatures favours renovations. The Z group will be uncertain goods beyond our influence, which are ordered randomly and in an unpredictable way.

Table 2. Division of stored materials according to the ABC / XYZ method [6]

	A	B	C
X	High level of demand, high consumption	Average level of demand, average consumption	Low level of demand, low consumption
	Precision forecast: high		
Y	High level of demand, high consumption	Average level of demand, average consumption	Low level of demand, low consumption
	Precision forecast: average		
Z	High level of demand, high consumption	Average level of demand, average consumption	Low level of demand, low consumption
	Precision forecast: low		

4. A PRACTICAL EXAMPLE

The technologies and methods described above were used in the project, which was realized in a door manufacturing company. In this project, the following conditions were proposed:

- means of transport and manipulation devices – a logistics transport system and devices which provide relocation of material from the warehouse to workplaces,
- storage facilities – devices which provide temporary storage of material before it is used,
- workers – the right number of workers responsible for warehouse processes,
- storage areas – the right storage areas, necessary for realizing logistic processes, fig 1.

An analysis of the currently used warehouse resources made it possible to assess the structure, quantity, technical parameters and effectiveness of using these resources. On the draft stage, the required structure of means is always compared to the existing one and a solution of disproportions between both data files (procurement of missing means, elimination of redundant means) is also a part of the draft. The need for means and the real level of their usage is one of the indicators of productivity and economy assessment of a logistics system.

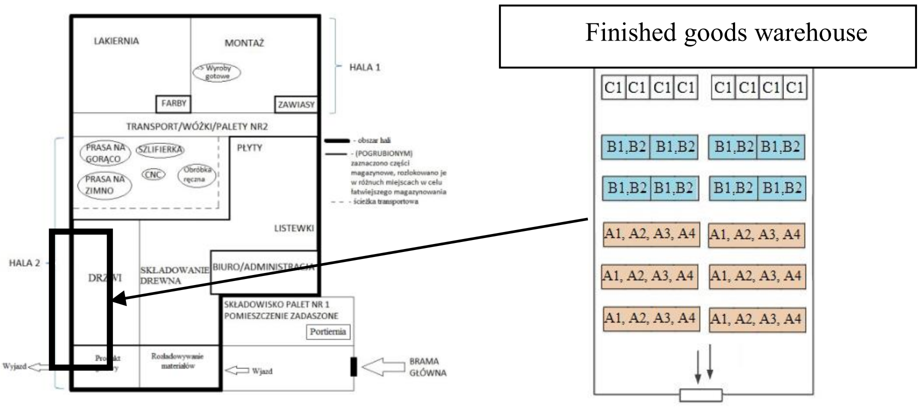

Fig.1. Arrangement of final products in the finished goods warehouse based on the ABC method

5. SUMMARY

Warehouse design is a process which is similar to production halls design associated with machining and assembly. The distribution of materials and transport routes are planned on the basis of the architectural foundation of the warehouse building, after which basic and auxiliary processes are improved thanks to applying various modern technologies such as RFID. Summing up the comparison of RFID and barcodes, the former technology seems a more practical solution. Taking into account today’s storage problems, it should be stated that logistic processes cannot be implemented without proper transport, modern automated equipment and efficient information flow. However, a well-executed ABC analysis allows to reduce costs and time of transporting materials to workplaces. The allocation of different materials to the right places of storage is currently the main problem related to designing warehouses. When we look for solutions that can be used in manufacturing companies, it is necessary to detect all factors, which may affect warehouse processes.

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Nature, Learning, Signs, Bionic.

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LEARN FROM NATURE

Abstract
The paper deals with the four most important signs from which we can learn from nature. Nature-inspired innovations are applied not only in different technology sectors, but also in management approaches and natural sciences. New trends in this area are becoming more used and they are slowly coming to the fore.

1. INTRODUCTION

Innovation is now a necessity for success. This applies to both manufacturing and service companies. The market has undergone transformation, companies have gone through private hands and entrepreneurs have determined the company`s future direction. The rate of their success and implementation of innovations are more or less directly proportional. To make a strategic decision to innovate has proved to be crucial.
New ideas are always born in one place, in the human brain. Knowledge and experience are used as a resource. Today, the brain potential of workers has become the largest capital in the world. The more they know, the faster they discover new solutions and technologies. Most examples are still found in nature. From nature, mankind has learned the basic principles of building objects, later people began to explore nature deeper, they became acquainted with the laws of nature and on their basic, the first technologies started to emerge.[1]

2. SIGNS OF LEARNING FROM NATURE

People have always learned from nature. It is the most natural source of inspiration and innovation. When we look at nature, we realize that all our inventions have inventions in nature in a much more elegant form, which is nature inoffensive. Our most sophisticated and most

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ingenious architectural gems, beams and pillars are already part of the arch of lilies, bamboo strains, human feet or bones. Our most sensitive radar is listening to bats with multi-frequency transmitters and receivers. And our new "intelligent materials" cannot be compared to skin dolphins or butterfly sapphire.
Millions of years of developed natural structures have undergone revolutionary changes, and during our development they have left us traces that we follow through with which they have improved. In studying the development of individual systems in nature, we come to a conclusion that there are certain trends and there are stages through which the natural structures have passed. Technical systems go through very similar stages. There are many signs we can learn from nature, the four most important are show in the following figure.

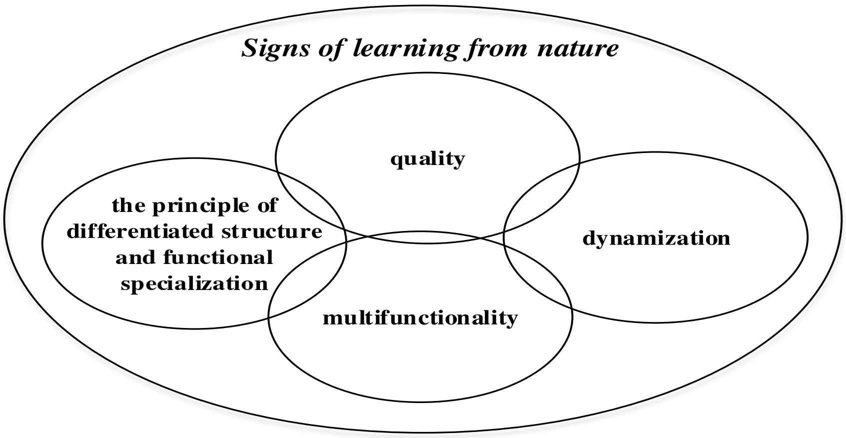

Fig.1. Signs of learning from nature

An important element is **quality**. An example is eye development. Insects, as a representative of a lower development group, have eyes composed of a small number of small eyes with a small resolution. Unlike them, the higher-developed existence as birds or humans, have eyes with two much higher resolution capabilities.
Similarly, it is in the world of technology where the quality and efficiency of products and services increases. We can find an example on television screens, once dominated massive black and white screens based on electron lamps. At present, however, we are looking at thin compact panels with high display quality, millions of colors and a fraction of harmful radiation. Progress in quality, with the quantity - the product size dropping significantly.

Dynamics in nature is characterized by the fact that biological structures are fluently adapted to the environment in their mutual interaction. This effect can be observed in nature in a wide range. Nature solves many technical contradictions by introducing dynamism.
Geese use to move the water surface of the feet that perform oscillatory motion. The area of the leg is decisive in engagement, the larger the area of the foot, the more energy the geese move on. The problem arises when reversing movement. A large area is suitable for the image, but a small surface for the return movement. The solution to this discrepancy is generally well known. They are flexible floating blanks placed between the toes of the foot. The geese take their fingers apart and they have the entire surface of the floating coating. In reversing motion, however, they

connect the fingers together, thereby reducing the area of the floating blanks and reducing the losses that would otherwise arise.[2][3]
In engineering practice, dynamization is a relatively expanded way of upgrading technical systems. A typical example is the airplane landing gear or landing flaps. Dynamic features already exist on more conventional devices: automatically fold-down mirrors for cars, headlight washers or retractable optics for compact cameras.

Multifunctionality is characterized by the fact that the structure, body or part of it provides more functions. Examples are insect. Depending on the type of insect, beetles can to capture ambient temperature, orientate, to determine the distance of objects, there is a ghost and a tactile organ in them, can recognize the turmoil of the air and thus estimate the direction and strength of the wind.
In the technique, multifunctionality is also desirable. We know it mainly from keyboards, computers or other device controls, where multiple clicks or presses of a given key combination are received. Adding multiple features to existing structures is one of the basic innovation processes.
The top of multifunctionality has reached today's mobile phones, which are no longer just phones, they are also watches, cameras, dictaphones, planners, alarm clocks, personal diaries, thermometers, game consoles, data storage, lamps, GPS navigators, etc. Multifunctionality in the current market has become a hit and the main subject of innovation. In this respect, the technique keeps pace with nature.

The trend of the differentiation of structure and functional specialization is a sign of advanced structure development, which has thousands of generations behind. It is assumed that the clusters of the same functional elements are at the beginning of evolutionary changes. They testify about this fossil. Over time, however, the individual elements are adapted to a specific function and begin to distinguish by shape, size, stiffness, etc. This is how we get to the more developed structures. According to this assumption, man's foreheads had, for example, the same fingers. Gradually their lengths, positions, shapes were changed according to their purpose.[4]
An example is Ford's well-known approach to mass production. In the 19th century, there was a trend of manufactory, where workers were always responsible for making the entire product from initial processing to the final treatment. Ford began production in the early 20th century, where specialized personnel were assigned to each line for each operation.
Henry Ford differentiated the structure of the business and specializing in the function of workers. The team has achieved significantly more efficient production, the concept of which has remained until today, when it can be said that his idea was revolutionary.

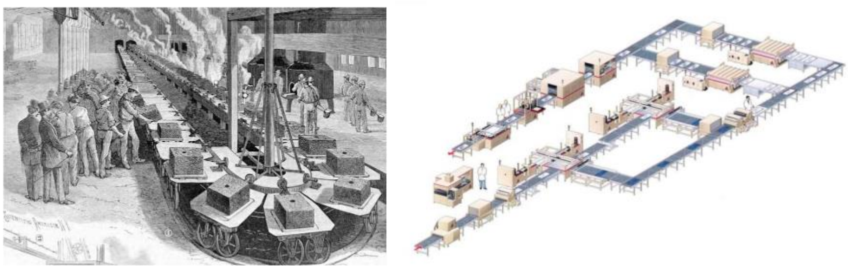

Fig.2. The Industrial Revolution in the production

3. NEW TRENDS IN BIONICS

Bionics is systematically focused on applying knowledge from the study of living organisms and their structures in the development of new technologies. Recently, sophisticated information, software and communication systems, which are parts of clothing and workwear (wearables), dresses full of sensors, cameras and processors, have come to the fore. They are already being developed and tested, and can be seen especially in the automotive industry. New trends include the Bionic Handling Assistant, Bionic Tentacles, Bionic Octopus, Bionic Cobot and Drones.
In the future, we can expect new discoveries in SMART technology and self-repairing machines. Increasing demands will be placed on intelligent systems that will be able to learn and adapt to changing requirements, tasks, situations and environments.[5]

4. CONCLUSION

But what bionics mean to us? There are hundreds of applications, but they are still in the minority. This condition is mainly due to the lack of development of materials and technologies. Many ideas from nature therefore cannot be realized either in the scope of mass production or in the scope of the prototype. However, research and development in the area of materials and technologies is progressing and creating a space for applying natural principles to technology. Therefore, in the future, the use of natural principles to solve technical problems can be expected to intensify.

This article was created with support of project: KEGA 020ŽU-4/2019

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Concepts, Traditional Maintenance 1.0, Maintenance 4.0, Industry 4.0, Transformation

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KEY CONCEPTS OF MAINTENANCE IN INDUSTRY 4.0

Abstract

Industry 4.0 is a name given to the current trend of automation and data exchange in industrial technologies. It includes the Industrial Internet of things (IIoT), wireless sensors, cloud computing, artificial intelligence (AI) and machine learning. Industry 4.0 is commonly referred to as the fourth industrial revolution. An important thing in Industry 4.0 is Maintenance 4.0. Maintenance 4.0 combines Machine Learning based Predictive Maintenance, Automation of Failure Reporting, Scheduling, Parts Management etc. and Robotics/Drone Assisted Repair.

1. MAINTENANCE 4.0

In the current manufacturing world, the role of maintenance has been receiving increasingly more attention while companies understand that maintenance, when well performed, can be a strategic factor to achieve corporate goals. The latest trends of maintenance leans towards the predictive approach, exemplified by the Prognosis and Health Management (PHM) and the Condition-based Maintenance (CBM) techniques. The implementation of such approaches demands a well-structured conception and can be boosted through the use of emergent ICT technologies, namely the Internet of Things (IoT), cloud computing, advanced data analytics and augmented reality. Therefore, this paper describes an approach of an intelligent and predictive maintenance system, aligned with Industry 4.0 principles, that considers an advanced and online analysis of the collected data for the earlier detection of the occurrence of possible machine failures, and supports technicians during the maintenance interventions by providing a guided intelligent decision support. [1], [2]

Maintenance 4.0 is a machine-assisted digital version of all the things we have been doing for the past forty years as humans to ensure our assets deliver value for our organization. Maintenance 4.0 includes a holistic view of sources of data, ways to connect, ways to collect,

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ways to analyze and recommended actions to take in order to ensure asset function (reliability) and value (asset management) are digitally assisted. For example, traditional Maintenance 1.0 includes sending highly trained specialists to collect machinery vibration analysis readings on pumps, motors and gearboxes. Maintenance 4.0 includes a wireless vibration sensor connected to a cloud server and machine learning platform to analyze the complex patterns and provide automated service advice to the asset owner. With Maintenance 4.0, the vibration specialist will no longer waste time going to the data; the data, when in need of subject matter expert analysis, will go to the human. The decisions are what we call "digitally assisted" – a partnership between man and machine. [3], [4], [5]

2. KEY CONCEPTS OF MAINTENANCE 4.0

We are in the midst of a transformation that started already a few years ago, nicknamed as the 4th industrial revolution. According to Klaus Schwab of the World Economic Forum it's all about 'industrial convergence'. That is the merger between the physical, digital and biological world. This is possible thanks to developments such as:

- robotization,
- nanotechnology,
- biotechnology,
- 3D printing,
- virtual reality,
- Internet of Things.

When we focus the '4th industrial revolution' on maintenance, we hear terms such as:

- Predictive Maintenance,
- IIoT (Industrial Internet of Things),
- Edge Computing.

The following nine terms update basic knowledge of Maintenance 4.0.:

- **Preventive Maintenance**

Preventive maintenance acts on the principle of 'prevention are better than cure'. Instead of waiting for a malfunction to occur, the intelligent software schedules a maintenance plan. The goal is to prevent failures before they occur. This contrasts with the old approach of 'Run to failure' maintenance which is reactive.

- **Industrial Internet of Things**

Industrial Internet of Things (IIoT) is one of the basic blocks of the 4th industrial revolution. Engineers are linking more and more components, installations and objects. This enables new analysis and insights. The most elaborated application today is predictive maintenance combined with big data analysis.

- **Predictive Maintenance**

Predictive maintenance goes a step further than replacing a certain part after a fixed number of running hours. The intelligent software looks at the part's health based on 'condition monitoring'. Condition monitoring uses data from:

  - vibration measurements,
  - oil analysis,
  - or infrared measurements.

The intelligent software predicts if a failure is likely within a certain time frame. Engineers can thus schedule and deliver maintenance better and decrease maintenance costs.

- **Big Data Analytics**

Monitoring your key installations delivers a large amount of data. This 'Big Data' contains a wealth of information. It is possible to predict the 'unpredictable' when you link information streams from inside and outside the company.
The PwC report 'Mainnovation' about Predictive Maintenance 4.0 shows this becoming reality. Top companies provide continuous asset monitoring with warnings based on predictive techniques. Regression analysis is one of those techniques.

- **Cloud Computing versus Edge Computing**

The evolution to store more and more data and to perform calculations in the cloud continues. Both for individuals and companies. Yet there are good reasons in the industry for doing Edge Computing. With Edge Computing your data remains close to its source for processing. It is a method to optimize cloud computing by performing data processing near the source of the data. It is the edge of the network. This is faster, safer and cheaper when you split between data stored and processed locally, and data sent to the cloud. [6]

- **Artificial Intelligence**

Large internet companies pump billions in research and development in the field of artificial intelligence. New breakthroughs follow each other faster and faster. The industry is working with cobots. They are robots that collaborate with and learn from human colleagues. Inspection drones and cleaning robots also start playing a larger role in the maintenance.

- **Predictive Analytics**

Predictive analytics encompasses a variety of statistical techniques from predictive modelling, machine learning, and data mining that analyze current and historical facts to make predictions about future or otherwise unknown events.

- **Prognostic Maintenance**

Prognostics is an engineering discipline focused on predicting the time at which a system or a component will no longer perform its intended function. This form of maintenance builds on predictive analytics and maintenance. It uses machine learning, pattern recognition, and other advanced techniques like 'neural networks' and 'neural fuzzy systems'.

- **Prescriptive Maintenance and Analytics**

The most advanced option in maintenance. Prescriptive maintenance tries to answer the question: 'What should we do to achieve X?'. It's based on:

  - big data,
  - graph analysis,
  - simulations,
  - complex event processing,
  - neural networks,
  - heuristics,
  - machine learning.

Prescriptive goes a step further than predictive maintenance because it not only reflects the possible results of a particular approach but also evaluates which approach is the fastest or most efficient. [7]

3. CONCLUSION

Revolutions are unpredictable and chaotic. [8] The adoption of Maintenance 4.0 has broad implications for the industrial sector. We do not have to assume a crude 'zero-sum game'—that for every winner there will be a corresponding loser. At the same time, many stakeholders will struggle to adapt. While we do not expect disruption to occur overnight, some of the traditional players are vulnerable and may not survive into the digitalization era.

This article was created with support of project: KEGA 017ŽU-4/2019

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Digitization, Predictive maintenance, Predictive maintenance 4.0, Industry 4.0,

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PREDICTIVE MAINTENANCE 4.0

Abstract

The main purpose of Predictive Maintenance (PdM) is to reduce unscheduled downtime and consequently improve productivity and reduce production cost. PdM has been featured as a key theme of Industry 4.0. However, the traditional PdM system was only designed for a single tool; as such, the resources allocation will become extremely complicated when hundreds of tools are working together in a factory. Predictive Maintenance 4.0 (PdM 4.0) is surely one of the most talked-about topics in maintenance and asset management.

1. INTRODUCTION INTO PREDICTIVE MAINTENANCE

The goal of Predictive Maintenance is to forecast & prevent equipment failure. (Fig.1.). Predictive Maintenance 4.0 is expected to drastically change the maintenance market. Besides the traditional reliability engineer we will begin to see new roles in the maintenance & asset management department: the data scientist.

Fig.1. Towards to Predictive Maintenance 4.0

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Predictive Maintenance is a set of activities that detect changes in the physical condition of equipment (signs of failure) in order to carry out the appropriate maintenance work for maximizing the service life of equipment without increasing the risk of failure. It is classified into two kinds according to the methods of detecting the signs of failure: Statistical-based Predictive Maintenance and Condition-based predictive maintenance. Statistical-based Predictive Maintenance (SBM) depends on statistical data from the meticulous recording of the stoppages of the in-plant items and components in order to develop models for predicting failures, while Condition-based predictive maintenance (also called Condition-based Maintenance, CBM) depends on continuous or periodic monitoring conditions of equipment to detect the signs of failure and make a maintenance decisions. Must be developed intelligent predictive maintenance solutions, which opens up innovative new possibilities for factories. Data generated by Cyber Physical Systems (CPS) and transmitted by IoT monitoring machine/process condition is automatically reviewed to pick up any patterns that indicate a possible fault through Data Mining systems. This decision uses Internet of Services (IoS) to allow the onset of a stoppage to be recognized early and corrective measures to be planned and introduced in the most effective way. It also means unplanned downtimes can be avoided and both staff and resources can be employed more effectively. Next pictures (Fig.2.) shows development of predictive maintenance. [1], [2], [3]

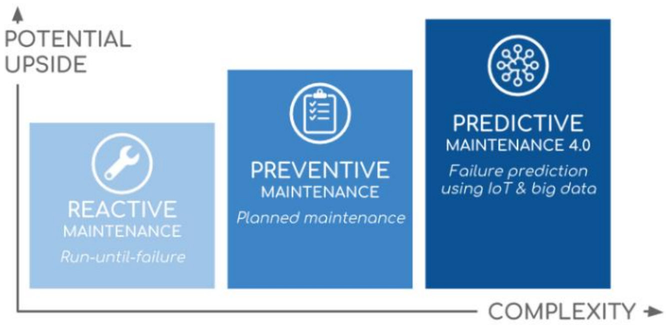

Fig.2. Towards to Predictive Maintenance 4.0 [1]

Description of the development stages: [4]

- REACTIVE maintenance is simple: “If it’s not broken, don’t fix it”. It’s best for cases where equipment failure is rare, easy to fix and with limited impact - e.g. switching a lightbulb in a warehouse.
- PLANNED maintenance (or preventive maintenance) uses routine maintenance to diagnose equipment for failure. It works and is widely employed - but it’s costly and doesn’t capture asset-specific conditions.
- PREDICTIVE maintenance leverages data from an individual asset to predict failure. This way, repairs can be done when needed (and avoided when not). It offers the best upside, but at the cost of complexity.

2. PREDICTIVE MAINTENANCE 1.0 TO 4.0

PdM 4.0 is seen increasing the predict-ability of the assets and the processes. Companies that apply PdM 4.0 will have a strategic advantage to their peers that steer away from PdM 4.0. The potential benefits of PdM 4.0 are very high. If maintenance has the ability to predict "unpredictable failures" we can take a big step in competitiveness. On the other hand, there are some major challenges: PdM 4.0 requires a huge change. A lot of companies focus on the technical and technological change but underestimate the organizational implementation. PdM 4.0 requires a complete culture change: PdM 4.0 tools will have another position in the decision process. The tools will suggest the moment to stop an installation or to change process parameters. This has to be embedded in the daily operations. In principle, predictive maintenance has been around for ages: When a technician inspects an asset and makes a change to avoid future failure, that's predictive maintenance. The difference is the amount of data that is used and the frequency of updates - cf. the overview of PdM 1.0-4.0. Below, we focus mainly on Predictive Maintenance 4.0, using IoT, big data and predictive analytics in near real-time. In particular, we'll dive into the sub sections of PdM 4.0 to show that this is still an extremely broad segmentation. [5], [6], [7]

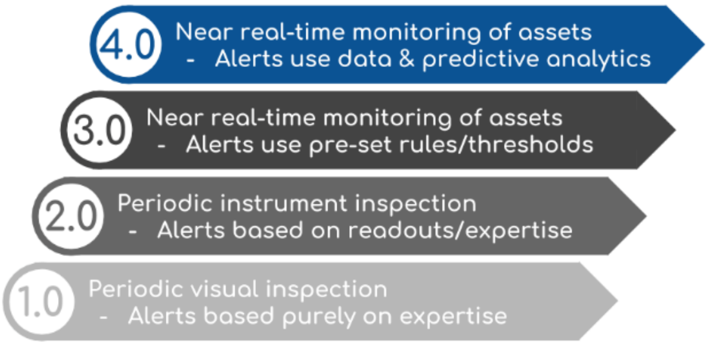

Fig.3. Predictive Maintenance 1.0 to 4.0

AI is perfectly suited to predictive maintenance. It offers a host of techniques to analyze the huge amounts of data collected from the manufacturing process and deliver actionable insights to reach and sustain manufacturing excellence. These techniques are referred to as Machine Learning algorithms. Industrial artificial intelligence can be applied to predictive maintenance and many other use cases in the manufacturing industry, and although we are just in the beginning of exploiting this technology, there are already many facilities benefiting from industrial AI. Predictive maintenance with machine learning looks at large sets of historical or test data, combined with tailored machine-learning (ML) algorithms, to run different scenarios and predict what will go wrong, and when. [8], [9]

3. CONCLUSION

Success with PdM 4.0 will ultimately depend on skills and knowledge of people in factories. Today environment shows that lack of skills or competencies in the company's workforce is the big-gest challenge for factories see when it comes to using data analytics. Factories generally understand that it is critical to have in-house data analytics capabilities in order to successfully drive Industry 4.0 applications. Building these capabilities takes, however, far more than hiring new talent with PhD's in statistics, data science or AI. PdM 4.0 cannot be implemented in complete isolation within the maintenance organization. It should be embedded into an overall digital manufacturing strategy that is owned and fully sup-ported by top management.

This article was created with support of project: KEGA 017ŽU-4/2019

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Maintenance, TPM, Pareto analysis, Lean manufacturing

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THE USE OF PARETO ANALYSIS IN ORDER TO INCREASE THE EFFECTIVENESS OF MACHINES

Abstract

Maintenance of technical infrastructure in the right condition is a prerequisite to ensure the stability of production processes. This aim can be realized (among others) through the use of proper methods and quality tools. This article shows the practical application of the Pareto analysis to increase the efficiency of machines' operation by eliminating the main causes of stops in the automatic molding line and implementation of effective corrective activities.

1. INTRODUCTION

Currently, the effective maintenance of technical infrastructure resources in an enterprise is one of the elementary factors determining the position of a given company in relation to competition on the market. This factor has a fundamental impact on the realization of the production process in a smoother manner and ensuring the predicted quality of manufactured products. All kinds of downtimes resulting from a failure have an influence on delays in the realization of orders and have a negative impact on the stability of the production process. Therefore, it is so important to implement corrective activities, effectively eliminating the cause of problems in order to prevent the recurrence of the problem. In order to accomplish this aim successfully, it is necessary to implement the total productive maintenance (TPM) strategy, which is one of the elements of the Lean Manufacturing, taking into account the use of appropriate methods of management tools, as well as the right organization of the work for responsible services based on the culture of continuous improvement. Lean Manufacturing is currently used by many enterprises, whose aim is to improve (constantly) their processes. Implementation of lean tools enables to improve the operation of the entire company through commitment and consequences in action. [1] [5].

2. CHARACTERISTICS OF TPM STRATEGY

The ideology of total productive maintenance (TPM) is based on proven solutions and techniques, the primary objective of which is to increase the efficiency of devices and machines

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used in production processes, ensure the stability of processes, as well as extend the service life and reduce the maintenance costs of machines and equipment, among others by limiting the occurrence of any type of machine park's failure. [1]
According to the guidelines of the TPM strategy's maker – S. Nakajima: "Mode and details of using the TPM system in order to maximize the efficiency of devices and machines should be adapted (in practice) to individual capabilities of an enterprise. Each company must develop its own plan of actions, taking into account the requirements and problems characteristic for the specifics of an enterprise, industry, production methods and the status of owned devices and machines". [2] According to this recommendation, it is obvious for this ideology that it must be personalized to the conditions of a given enterprise, taking into account its specificity.
An integral element of the total productive maintenance strategy is the use of a variety of data analyzes and measures, which are aimed at providing information about the effectiveness and efficiency of conducted actions and constitute the basis for making the right decisions from the point of view of the company's interest. Various measures are defined in the literature to evaluate the supervision of machines, among others OEE, MTTR, MTBF. The crucial meaning for the implementation of the PTM strategy in the organization is to build adequate attitudes among employees and increase their awareness. [3].

3. CHARACTERISTICS OF PARETO ANALYSIS

Pareto analysis is an efficient tool for effective troubleshooting through the prioritization of problems in accordance with the most important reasons. It is worth noting that Pareto enables the prioritization of actions and directs organizations during the determination of an action plan in order to increase the efficiency of machines, while avoiding dissipation of resources for all causes at a certain moment. This enables focusing of those problems, the elimination of which allows to reduce the problem in the best possible way and improve the efficiency ratios of machines. The Pareto analysis enables to identify and categorize problematic areas, and on this basis – by systematic elimination of problem sources, improve the production processes and ensure the required quality and timely delivery of products. [4]

4. EXAMPLE OF THE ANALYSIS OF MOLDING LINE'S STOPS

The aim of the researches, the results of which are presented in this article, was to show the real actions conducted by the examined enterprise in the field of data analysis for stops that are the biggest problem in the effective use of normal time of machines. The researches were carried out in Metalpol Węgierska Górka sp. z o.o. (enterprise). Metalpol is a manufacturer providing products for the railway, automotive, machinery, mining, agricultural, construction and public sectors from gray cast iron EN-GJL-200, 250, 300 and from spheroidal cast iron EN-GJS-400-15, 500-7, 600-3, 700-2. Moreover, the plant manufactures industrial valves.
The following analyzed data was obtained on the basis of the registers of stops for molding lines, which form the basis for the creation of Pareto analyzes. This work focuses on an automatic vertical molding line. The mentioned technological process includes molding machine, CIME pouring device, grating shake-out, refrigerator, mass processing station and accompanying appliances. The Pareto analysis for the failure rate of the examined molding line in the period of one month showed that the biggest share of time in stops connected with its failures has a grating shake-out, vibrating chutes and a large filter, responsible for drawing the dust fraction from

moulding compound (Fig. 1). The analysis was conducted on the basis of data from the register of stops and it refers to stops in all production shifts.

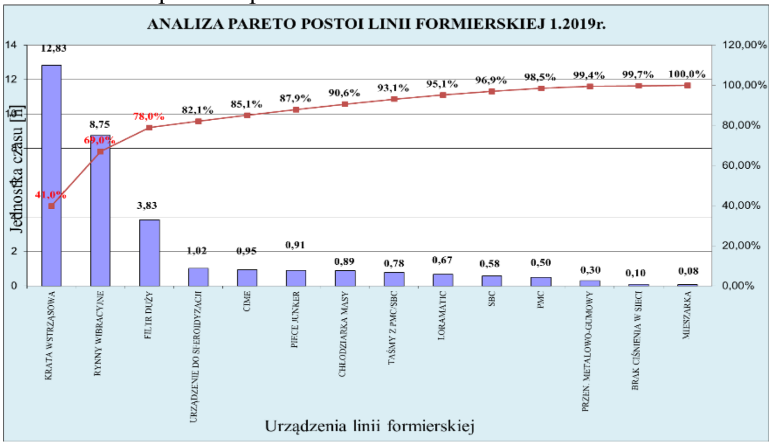

Fig. 1. Pareto-Lorenzo diagram for total break times in the operation of a molding line in 01.2019

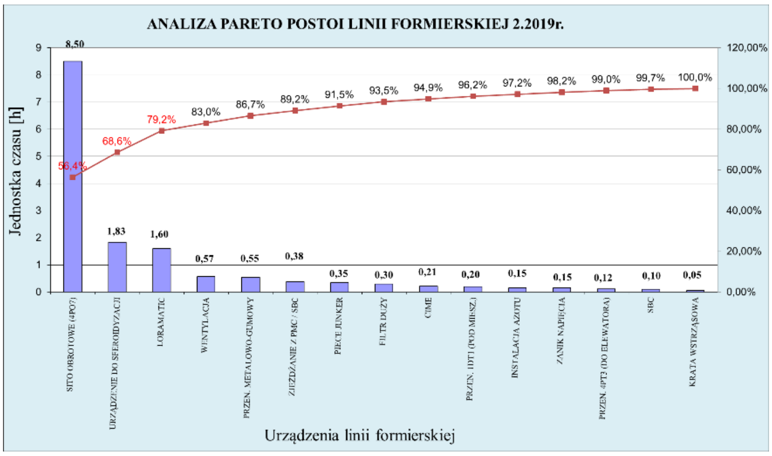

Fig. 2. Pareto-Lorenzo diagram for total break times in the operation of a molding line in 02.2019

On the basis of the device's inspection, it was found that frequent failures on the grating shake-out were caused by notorious cases of tearing bolts securing the drive motor of the grating shake-out. After the diagnosis and inspection of the damaged elements, it was found that the reason for breaking screws was incorrect adjustment of the drive motor to the mounting socket. Due to this fact, re-planning of the surface was carried out in order to ensure that the vibrator's seat is properly fitted to the drive motor. On the other hand, the source cause of failures connected with the vibrating chutes was the breaking of the drive. After the diagnosis, it was decided to replace the set of bolts with a set characterized by a larger diameter and a higher strength class (12.9).

Additionally, as a part of preventive actions, personnel was trained and the daily monitoring of loosening screws was entered into the operator's TPM card. Large filter's failures were caused by damage to the inverter controlling the motor's operation. The high level of dustiness has contributed to the inadequate operation of the inverter. Therefore, after a deeper analysis of the problem, it was considered that the hermetic enclosure of this device should be conducted. Furthermore, a circuit supplying air from outside (it helps to ensure adequate underpressure) and an air conditioner (to ensure an adequate working environment) were installed inside the housing. As you can see in the above chart, in the next period there were not problems connected with the highest percentage of all failures that occurred in January. Moreover, it is worth mentioning that the effects of activities can be observed in the improvement of the MTBF index, which amounted to 31.12 hours (in January), and 45.70 hours (in February).

5. SUMMARY

In the last few years, enterprises have been undertaking actions (on a large scale) aimed at improving the efficiency of owned machinery parks, within the framework of the TPM concept, through the continuous elimination of losses resulting from unwanted stops in the operation of devices and machines, as well as undertaking preventing activities aimed at eliminating failures. The article shows the practical use of the Pareto analysis, which effectively helps to identify the right course of action in the field of increasing the efficiency of machines through the prioritization of existing problems. The Pareto analysis is a tool utilized to improve the production processes by ensuring the stability and continuity of their implementation. [4] [6]. The Pareto analysis is one of many quality tools that can be successfully applied as a part of the TPM strategy, the aim of which is (primarily) to increase the efficiency of the use of owned machines and devices. [1]

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Generation Baby Boomers, generation X, generation Y, generation Z, motivation

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MOTIVATION IN CONTEXT OF GENERATIONS

Abstract

The paper deals with motivation in workplace in the context of employee generations. The first part describes active generations and their work habits. The second one defines research questions and presents the research sample. The third part analyses results of the research. The final part valuates the importance of impact that motivation has on the job performance.

1. INTRODUCTION

The term motivation origins in Latin “movere”, to move. There are two explanations: Motivation keeps us moving, and it also means change, movement inside us. Motivation in work process is defined as purposeful process of improving individual abilities, that are supposed to activate required behaviour and activities [1].

The research in the paper focuses on motivation in workplace in context of employee generations. At the time there are four active generation in the labour market: the Baby Boomers generation, and generations X, Y, and Z [2].

The Baby Boomers (abbreviated BB) generation consists of people born in 1946 – 1964, in the age of economical and intellectual prosperity. They come up with new ideas and re-evaluate conventional ideas. They tend to spend their whole professional life in one company, and they usually subordinate personal and family life to the work success [3].

The X generation, people born in 1965 – 1981, brings changes in social values. For these personas is typical strong individualism, scepticism and informality, and aspiration to personal progress [4].

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Generation Y, people born in 1982 – 2000, is growing up in a liberal world. Relationships are formed in the workplace, so time spend working and socialising overlaps. They profit from working in new companies that absent fixed hierarchical structures [5].
Z generation, the youngest one, consists of people born after 2000. They are the first ones who does not have to adjust to new technologies, but take them as a part of life instead. They excel in quick relationship-building. Geographical range is not an issue anymore. They share and accept opinions of different nationalities and cultures [6].

2. RESEARCH PROBLEM

These days, industrial enterprises in Slovakia suffer from long-term lack of suitable labour force. There is problem with finding new workers and retaining the actual ones, mostly in term of big companies. The aim is to keep employees motivated, and to support creativity, relationships and job performance.
The enterprise we executed the research in is an industrial decentralized organization with eleven divisions worldwide, responsible for commodities, markets and achievements, serving as profit centres. The company follows the global trend and focus on the age management in the context of employee motivation.
The stimuli with direct impact on motivation differ for every age group. Satisfaction is an individual issue, connected to personality, experience, expectations and subjective view of a social environment. Companies are responsible for establishing an adequate environment, where fulfilling of the working goals is a resource of self-realization. That is a crucial condition for motivation of employees to improve their job performance. These motives and stimuli have to be investigated individually for every generation in the company.

2.1 Research questions

The main goal of the project was to characterise employees' motivation in the context of generations for a sample of a real-world company. So, two research questions were defined:
RQ 1: Which factors of non-financial (intangible) motivation have a positive impact for job performance and satisfaction of employees?
RQ 2: Which factors of material (financial) motivation have a positive impact for job performance and satisfaction of employees?

2.2 The research sample

The enterprise employs people from every mentioned generation. In the research that we did as a part of our project took place 148 participants. Their stratification amongst generations can be seen in the table (Tab. 1).

Tab.1. Percentual rate of the participants according to generations (own elaboration 2019)

	BB	X	Y	Z
Employees in the company	104	332	429	20
Respondents	47	42	52	7
%	31,76	28,38	35,14	4,72

2.3. Data collection tools

The enterprise performs periodical research among the employees regardless of their position within the company. The aim is to expose factors of motivation and demotivation, and to determine the satisfaction ratio. We participated in this research, and we analysed the results in the context of employee generations.

3. EVALUATIONS OF THE RESEARCH QUESTIONS

Evaluation of the 1st RQ:
The figure (Fig. 1) shows which factors of the non-financial (intangible) motivation have impact on job performance of the generations. The Baby Boomers generation was almost unresponsive to this type of motivation, the exceptions being start of the work in early hours and home-office. For generation X, the most important is career growth, what corresponds with the preferences of generations Y and Z. Generation Y is the most motivated in this case, greatly interested in home-office, what also points to educational attainment and workload of nonmanufacturing character.

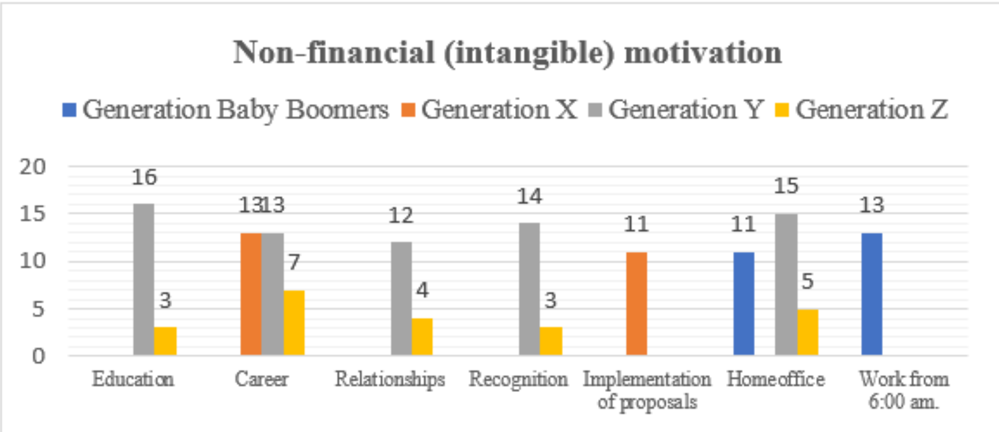

Fig.1. Non-financial (intangible) motivation (own elaboration 2019)

Evaluation of the 2nd RQ:
As the research provides (Fig. 2.), financial assessment is the most factor of material (financial) motivation for every generation within the company; that means increments and bonuses. The older generation, Baby Boomers and X, that have been in the company for a long time, await classification into higher job classes. Generations X and Y are motivated by more days of occupation leave, as many of them work shifts and they want to spend time with their families. Employees of the oldest and the youngest generation, who do not have small children, are not so much motivated with occupation leave. For Baby Boomers generation, corporate events are important, because of their need for being part of the organization they are working in. Younger generations, mostly generations Y and Z, are also motivated by material gifts and by delegation of a company car even for non-company purposes.

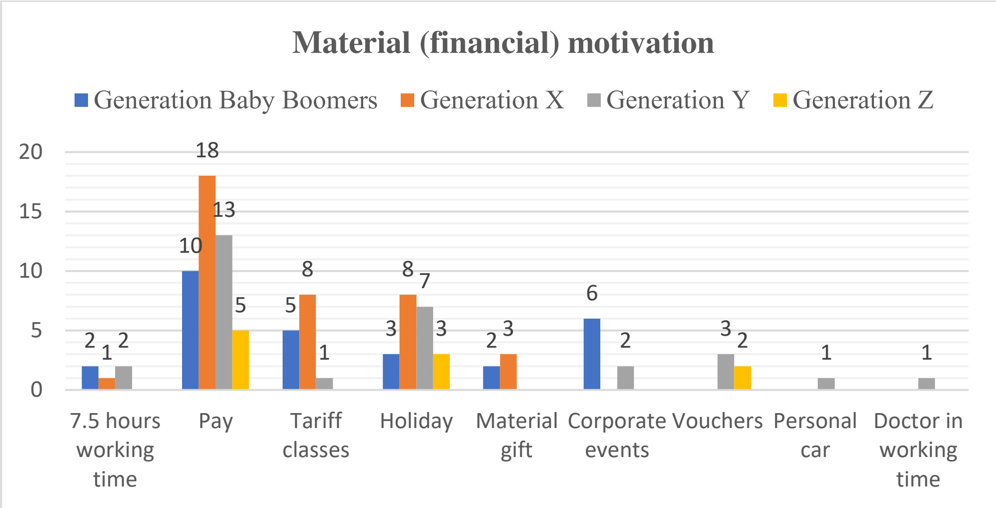

Fig.2. Material (financial) motivation (own elaboration 2019)

4. CONCLUSIONS

In the process of evaluating results of the research we identified actual motives that improve the job performance of employees. As the research demonstrated, the older generations are not satisfied by the intangible motivation, it provides them no adequate stimuli. We interpret it as a negative feature of the motivation system of the company. Material motivation is important for every generation, primarily financial assessment, occupation leave and shortened work time. This information should be considered, as motivated employees are a huge contribution for their colleagues, their company and even for themselves.

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Simulation, Emulation, Logistics system

Róbert HODOŇ*, Róbert Žalman**, Andrej Štefánik***

THE BENEFITS OF EMULATION IN LOGISTICS SYSTEM

Abstract
The structure of logistic systems is designed to include flexibility into their characteristics, in the form of rapid adaptation to changing market conditions. In addition to the real manufacturing system, companies also have a digital manufacturing system, represented by digital model integrated into the digital enterprise. In the future, by combining monitoring systems and parametric simulation models it is possible to reflect real world behavior based on the virtual environment. Such a comprehensive system will enable us to adapt real logistic systems into the virtual environment.

1. INTRODUCTION

The current trend in logistics development says that it only wins the fastest, cheapest and most effective in terms of logistical productivity. The design of logistics systems is designed to incorporate flexibility into their characteristics, in the form of rapid adaptation to changing market conditions. With the advent of digital technology to the industry, happen a new period, also called as digital enterprise. In addition to the real manufacturing system, businesses also had a digital manufacturing system, represented by digital models integrated into the digital enterprise. Using a digital enterprise, it is possible to analyses the efficiency of production systems before performing a precisely defined change in real production. For this reason, it is essential to focus on the rapidly changing requirements of capacities and functionalities that we call reconfigurable logistics systems when designing logistics systems. Reconfiguration of the logistics system is based on the current need to design logistics concepts in smart factories. Nowadays, it is already possible, based on monitoring systems, to dynamically change automatic logistics facilities on predefined circuits. In the future, by combining monitoring systems and parametric dynamic models, it is possible to reflect real world behaviour based on the virtual environment. Such a comprehensive system will enable us to adapt real logistics systems to a virtual environment in the future. Current logistics systems use huge amounts of data that result from sensor use. Software solutions and their development have become an essential part of the further development of logistics systems. By combining computer simulation with real logistics

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systems, it is possible to create complex solutions to meet the requirements of enterprises in building intelligent logistics systems.

2. SIMULATION AND EMULATION IN LOGISTICS SYSTEMS

In modern industrial practice, innovative solutions are continually proposed for the improvement of processes and/or entire production or logistics systems. There are many options offered, but the problem arises in verifying the correctness of the decisions and their impact on the functioning of the logistical processes and the entire production system after the implementation of the changes. Forecasting or experimentation can be carried out, but there are also more appropriate methods of verification, as the changes can have a significant economic impact on the enterprise. Such instruments are simulation and emulation, as the simulation is an effective tool for detecting potentials in production and logistics, and also eliminating shortcomings in the design phase of a particular solution in the enterprise. Another proposed intelligent solution is emulation, as part of the decision-making and management systems. The resulting design of the simulation-emulation logistics system allows a significant decrease in the time of the production system to operate (Fig 1). The emulation of production systems is also intended to quickly verify the impact of the management principles in advanced production systems for discrete production.[1,2]

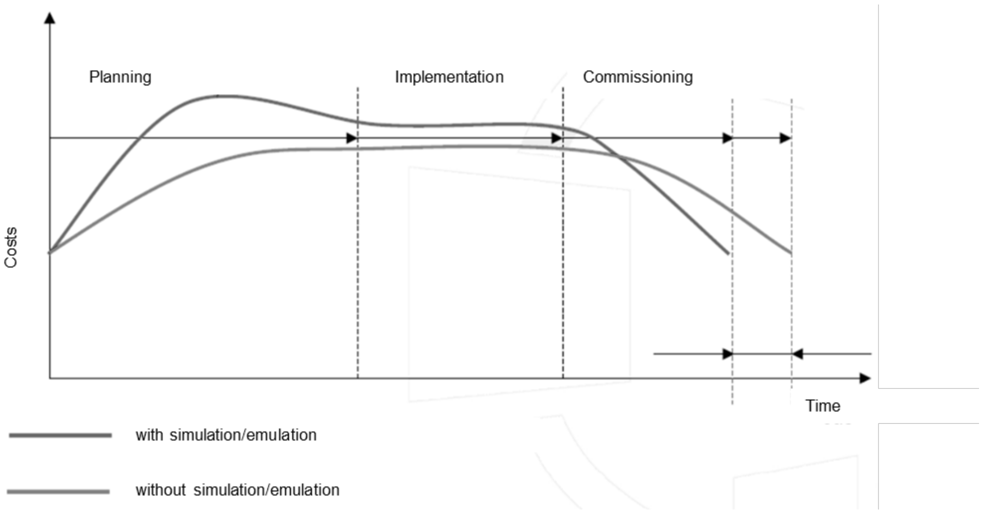

Fig.1. The benefit of using simulation / emulation to implement the production system

2.1 The problems and solution of current design of logistic systems

The use of computer simulations in the planning and design stages of logistics systems in enterprises is nowadays widely widespread. However, its use ends with the verification of the proposal before the system is acquired and its launch (Fig. 2). At present, a system is not designed to transform the simulation model into an emulating aid as an input generator of tasks when deploying logistics and to test logistics and its information systems. As the simulation can shorten the planning process and prevent design errors, emulation can help solve problems especially when testing the communication of manufacturing, logistics and information processes. The use of such a system would entail the removal of the need for physical deployment of all production facilities for testing the functioning of logistics and would be able to eliminate errors prior to the acquisition of all machines and the production run.

The application of this solution is illustrated in the Figure 2. Shows the current state of logistics implementation. This is a cycle consisting of the following steps:

- Conceptual Design - design by projection planning tables based on static calculation.
- Dynamic Simulation – verify the conceptual design through dynamic simulation, which considering on the effect of time.
- Purchase and installation of equipment – this step includes steps such as device selection, vendor selection, purchase and installation of equipment in real operation.
- Real Logistics.

The part, which represents us savings, was created by moving the test phase to the procurement and installation phase. By continuing with emulation, it will not be necessary to have all production facilities available and therefore the phase of testing of logistics processes may already be at the installation stage.[3,4]

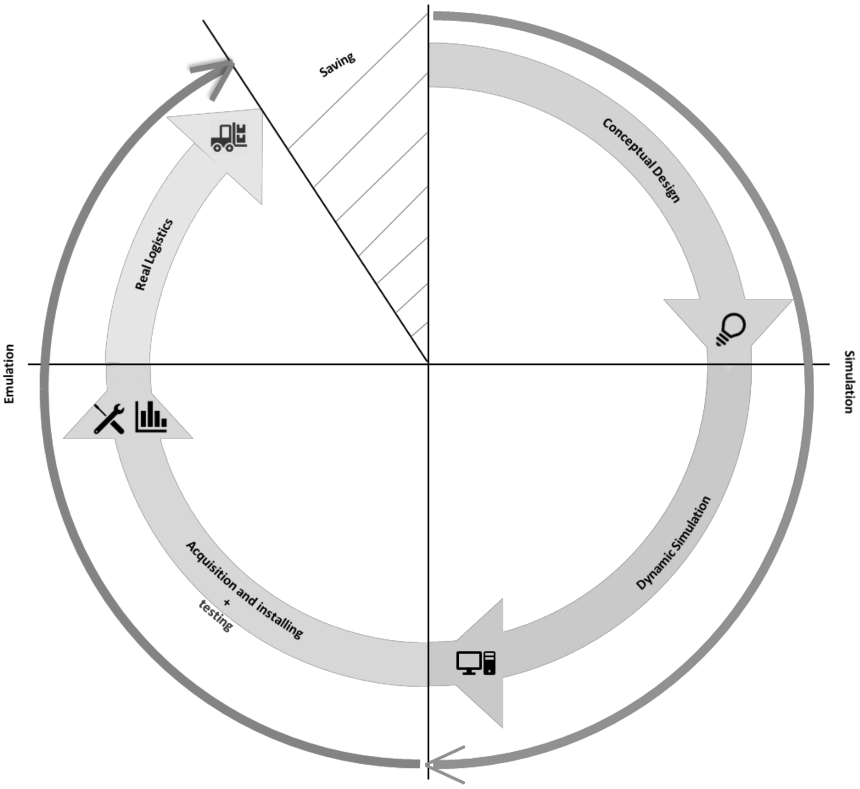

Fig.2. The benefit of using simulation / emulation to implement the production system

3. CONCLUSION

The article discusses the need to design a system for testing logistics processes in real conditions before installing devices. As production and delivery of production and assembly equipment is a time-consuming process, the possibility of testing the logistical system provides a competitive advantage in a dynamically evolving market. Testing of logistics systems within an enterprise with a link to emulation is possible in two different ways.[5] In the case of production which does not possess real production facilities or new equipment will be added to existing production, it is possible to test the behavior of real logistics by means of virtual production facilities which will be replaced by simulation software. The second case is if the enterprise has real production facilities and plans a change in the functioning of the logistic system or the deployment of automated logistics. Here, using emulation can be proposed in the simulation software virtual logistics, which will then be tested and optimized for real production requirements.[6]
Further research will be needed to develop dynamic, object-oriented models that will represent examples of real-world resources as well as semantic representation for modelling of intangible assets at the operating level. In the future, the goal is to create a link between logistics devices and a model that interact with each other and work with data in real time. This will allow you to track the movement of the equipment, stock inventory status and plan production based on these data..

This article was created with support of project: KEGA 020ŽU-4/2019

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Dynamic workplace, Static load, Ergonomic chair

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IS ERGONOMIC REALLY ERGONOMIC? - MARKET INVESTIGATION OF ERGONOMIC CHAIRS

Abstract

The number of professions tied to a seated working posture in the industry today is increasing. The static load on the worker during long-term sitting has a negative effect on muscle function, the cardiovascular system, and ultimately on worker performance. The article deals with the possibility of reducing the effect of static load through a dynamic chair. At the same time, it presents the results of a survey of the Slovak market in the field of ergonomic chairs, which serves as a valuable source of data for the design of a dynamic workplace.

1. INTRODUCTION

To optimize human activity and eliminate physical stress, industrial engineering, as well as ergonomics, seek to reduce the distance and frequency of movements to the lowest possible level. This low level of movement ensures their economic efficiency and at the same time, allows for a smooth flow of production without unnecessary breakdowns. On the other hand, the standardization of movements and the working space where the worker has everything at hand is heading towards increasing the static component of the work. The issue of static load arises as a result of the optimization of work activities, and the natural development of industry towards digitization, implementation of technologies in the production process and elimination of manual work [2][3]. Due to the natural human need to facilitate or completely replace manual work with machines, human activity focuses on the development, design, and management of machines.

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This gradual change in the structure of the industry due to rapid technological developments causes a growing trend in the number of workplaces with the primary seated working position.

2. ERGONOMIC DYNAMIC CHAIR

It is scientifically proven that the load on the lumbar spine - the transition between the L and S spine segments is more significant in the seated position compared to standing [1]. Ergonomic chairs are developed based on the need to eliminate the long-term static load on the spine, back muscles, and leg muscles, which is directly related to the increasing number of sedentary jobs. A static sitting position leads to tension in the muscles and can even lead to permanent damage in the long run. Likewise, long periods of relaxation weaken the muscles and prevent them from doing their job correctly. The transition between exertion and relaxation through dynamic sitting is the best way to prevent it.
The principle of a dynamic chair is based on a sitting on therapeutic ball. Sitting on a therapeutic ball ensures the muscles responsible for maintaining balance in the abdomen and back. The benefits of a good ergonomic dynamic chair:

- Changes the position of the spine regularly,
- through the change of position, nutrients are supplied by intervertebral discs,
- stimulates complex back muscles,
- keeps more than 40 joints in the spine in motion,
- optimizes blood circulation,
- correct blood flow maintains the processes of brain metabolism and thus attention and concentration.

3. THE RESULTS OF MARKET INVESTIGATION

The parameters of the essential parts of the office workplace are also enshrined in the Slovak legislation. Regulation of the Government of the Slovak Republic no. 276/20016 defines adjustable seat height, seating area interval, backrest height and tilt adjustment, and forearm height adjustment for office chairs [4]. Based on the parameters defined by legislation, ergonomic knowledge, and discussions with experts in the field of physiology, the expert team generated parameters that should be fulfilled by an ideal dynamic, ergonomic chair. The presence of these parameters was subsequently detected in chairs offered on the Slovak market under the name of ergonomic or health. Monitored parameters were:

- seat height adjustment,
- variable seat depth,
- seat back inclination independent of the backrest,
- the backrest slope,
- adjusting the backrest height,
- adjusting the height of the lumbar support,
- adjustment of lumbar depth,
- height adjustable forearm rest,
- adjusting the armrest angle,
- headrest,
- dynamic sitting.

The percentage of the number of chairs that met the given parameters is shown in Fig. 1 and Fig. 2.

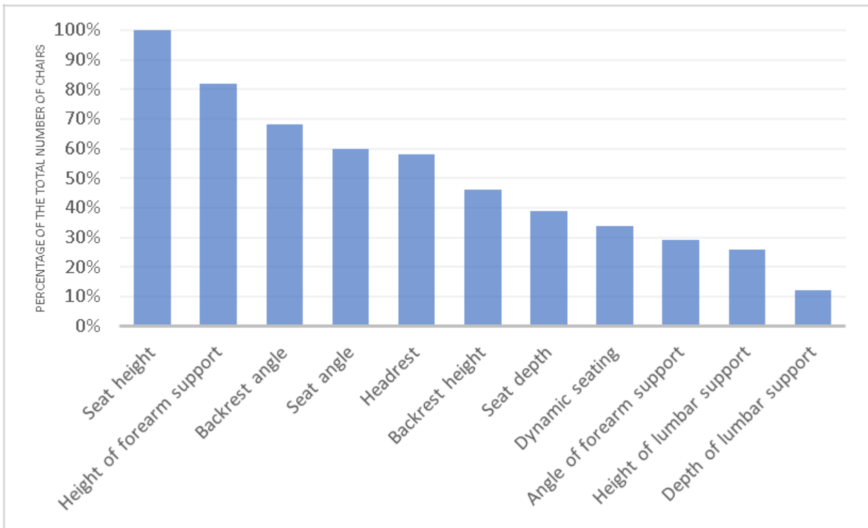

Fig. 1 Percentage of the number of chairs meeting the individual parameters

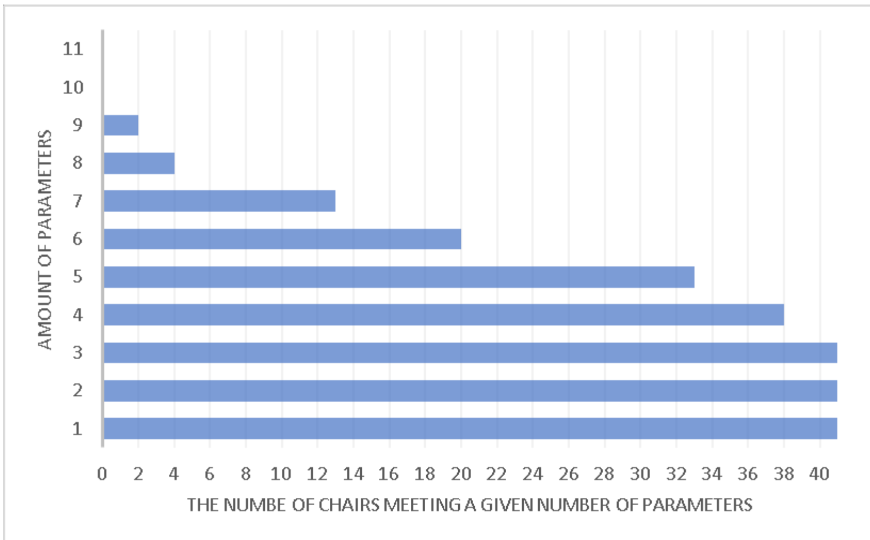

Fig. 2 Number of chairs meeting the given number of parameters at the same time

As can be seen from the survey results, the possibility of adjusting the height and depth of the lumbar support was the lowest among the analyzed chairs. However, the possibility of adjusting the lumbar support according to the user's physiology is crucial to maintaining the correct position of the spine in the sitting position. Only 24% of the total number of monitored chairs fulfilled the minimum requirements for an office chair defined by Slovak legislation. The Fig. 2

shows the number of chairs meeting the given number of parameters at the same time. As can be seen, none of the chairs met all of the parameters under review. Just two chairs met nine of eleven parameters simultaneously. Chairs that offer the possibility of dynamic sitting, on the other hand, showed a significant deficiency in other parameters.

3. CONCLUSION

The modern human population ceases to move during work but also in non-working life. The consequences of such a lifestyle have been known for decades - obesity, cardiovascular disease, posture disorder, and ubiquitous stress that affects the population's health as gray eminence. Due to the natural development of the company towards the implementation of technologies simplifying and speeding up the work process, the number of professions with the primary seated working position and thus the static load of the organism increases.
However, the chairs available on the market today do not have all the parameters that can be considered key to reducing the impact of static loads. In principle, they meet the basic requirements of adjustability, but only a fraction of the products allow dynamic sitting, which is necessary to eliminate static load. However, long-term dynamic sitting on such a chair causes the same difficulties as a static load because deep muscular structures responsible for maintaining balance are activated continuously, and for prolonged periods, there is over-power and subsequent pain. For this reason, it is necessary to determine the right boundary for the dynamics of such a chair. Last but not least, it is necessary to take into account the effect of the human factor on the chair setting itself. The actual implementation of an ergonomic workplace chair does not guarantee its proper use. At the same time, it is necessary to combine the ergonomic chair with the height-adjustable table. Only a combination of a dynamic table and a dynamic chair ensures maximum adaptation to the anthropometric and anatomical characteristics of the worker. Further research into sedentary employment and a new challenge for ergonomics is to develop an intelligent adaptive dynamic workstation that autonomously adapts to its user without its intervention and, based on predefined time intervals, would ensure an effective change of position.

This article was created with support of project: KEGA 022ŽU-4/2019

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INNOVATION IN TEAMWORK

Abstract
One of the difficult tasks that are needed to accomplish in the role as some team leaders is to earn the respect of employees. Being in charge is not going to get them the respect you are looking for. They have to work towards earning respect and it does not come easy. When the team leader is respected by one and all, the enterprise grows. The work gets done in an efficient manner, the clients stay loyal. The paper deals with steps to keep employees respect.

1. INTRODUCTION

The issue facing many business owners is that they lack the foresight to understand that respect is directly linked to the control and authority they have over their business. Whether it is dealing with employees or clients, respect plays a key role in convincing the other party to agree with team leader viewpoint. The employees do respect team leaders from the outset. After all, they are the one providing them with livelihood and they cannot ask for more. However, over time, they have to make sure that respect stays intact.
Once the manager (team leader) starts losing respect, the house of cards can collapse very quickly. The employees are no longer determined to follow his lead. He will see that the inefficiency increases, productivity take a tumble and the overall work environment suffers. This is obviously not the position he wants to be in. Even if it is only one employee who feels that way about him, it doesn't take long for their attitude to rub off on other employees. Sooner or later, the problem can grow beyond his wildest expectations. A failure to recognise the problem only increases the cause for concern and makes it difficult for you to deal with the situation. There are several reasons why one employee might not respect you the way they did before. The most common example is an employee being passed over for a promotion or not getting the raise they expected. Whatever the reason (justified or not), the problem has to be dealt with quickly. And it does not take much to lose respect. You don't have to be

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Miranda Priestley to be hated by your employees. Often, the reason why business owners end up losing respect is because of small things they could have easily changed or fixed had they made the effort. Overworking your employees and not praising them and their contribution (when warranted) often enough, placing excessive stress, not providing a healthy working environment, are all factors which contribute to your declining respect.
This paper is structured in the form of four main sections, where are demonstrated concept of recommentation to innovate the team work. In section 2, steps that can help with gaining and keeping employees respect and continuing to look up to team leader as a boss is presented. Finally, a short summary and an outlook are given in the conclusion (section 3).

2. STEPS TO GAIN AND KEEP EMPLOYEES RESPECT

In some cases, it is the way the team leader manages its employees, which leads to them losing respect for them. They cannot always blame their employees for the problems plaguing the business. For instance, if you know of a certain employee who has not been performing optimally and slacking off instead of focusing on work, he should see that employee right away. Delay in dealing with the problem and he can no longer blame the employee. It was his lax attitude which contributed to the problem.

Fig.1. Four steps to gain and keep employess respect

More difficult than gaining the respect of employees is reclaiming it after team leader has lost it. Thankfully, there are some practical steps that can take to do so:
Keep Your Eyes and Ears Open – team leader needs to keep your eyes and ears open. If you observe any employee behaving differently or not performing to the level you expect, it is time for a one-on-one meeting. You have to pick up the signs which could help you find out if something is wrong. Else, you would continue losing respect.
Address the Issue - Once you have discovered there is some issue which is affecting the employee's respect towards you, you should take the time to address it right away. As mentioned above, delaying dealing with the problem only intensifies the problem and puts you at fault.
Analyse the Situation - While addressing the issue, it is important for you to see if the lack of respect has been rubbed off on other employees as well. You might have to deal with a number of people, not just the one you noticed in the first step. [1], [2], [3]

Clear the Air - Accept if you are at fault, but not if it is clear that the employee is the one causing the rift. Not owning up to your mistake could lead to further respect issues with the said employee. Clarify what you expect of the employee and ask them to tell you about their expectations of you. Only then would you be able to clear the air.

Whatever you do, provide the employee a chance of being heard. Don't react impulsively and penalise the employee. It would lead to further problems and the issue would only intensify instead of being resolved.

How to Gain Respect from Employees - You would only need to reclaim the respect of your employees if you lose it. There are some practical steps you can take for gaining respect which prevents any such situation from arising in the future. Here are the steps you can follow to earn your employees' respect.

Enhance Your Management Skills - The key to earning the respect of your employees is to understand the fact that you are dealing with a diverse group of individuals. Not all of them can be handled in the same way. This does take some doing, but ensures you can deal with each employee in the best possible manner. That way, none of them harbours any grudge or animosity towards you which ensures your respect remains preserved. Deal with each employee according to their personality and you will reduce the risk of any problems emerging.

Be Available - There is no doubt that you are going to be pressed for time day in, and day out. As a business owner, you initially may feel like hardly anything gets done without going through you first. In such a routine, this attitude and expectation can make your employees feel as though you don't respect them enough to get the job done that you hired them to do. However, you to need to make yourself available for your employees at any time they really need your advice. This doesn't mean you have to drop everything you are doing, which isn't productive.

It means having time available on your calendar when employees can schedule meetings with you so you can give them your undivided attention. Give them the time they need to voice a concern or seek consult on any issue and they will respect you. Deny them the opportunity and you virtually asked them to stop respecting you the way they do.

Help Out Whenever Possible - Providing a willing ear is important and so is a helping hand. Whenever you get the chance, help out your employees. If an employee has to stay late to complete an urgent project, offer to stay too. It is a small gesture but one which shows that you genuinely care for your employees. Do this and they will continue to respect you. However, this does not mean that you have to do the work for them. Just offer a helping hand and that's all. You are already working more hours than your employees and take all the risk, but when they occasionally actually see you when they are staying late, it can make a difference.

Offer Suggestions Instead of Giving Orders - Being in a position of power makes it tempting for you to control the way your employees behave and work. Surely, you would have seen many entrepreneurs barking orders at their employees when they want to get something done. Though the work gets completed, it often leads to animosity towards the employer. The better approach would be to offer suggestions and ideas instead of giving curt orders to your employees. They will appreciate it much more than getting directions on how to do their work. Getting them to think outside the box for themselves will only help you and help them grow too.

Therefore, as team member proximity decreases, teamwork quality has a stronger impact on the team's ability to effectively and efficiently complete its project. This has been documented empirically by Hoegl, Ernst, & Proerpio, and Figures 2 and 3 demonstrate this moderated relationship. In their study, team effectiveness relates to the quality of the software products designed and developed (e.g., functionality, robustness), while efficiency refers to the adherence to project schedules and budgets. [4]

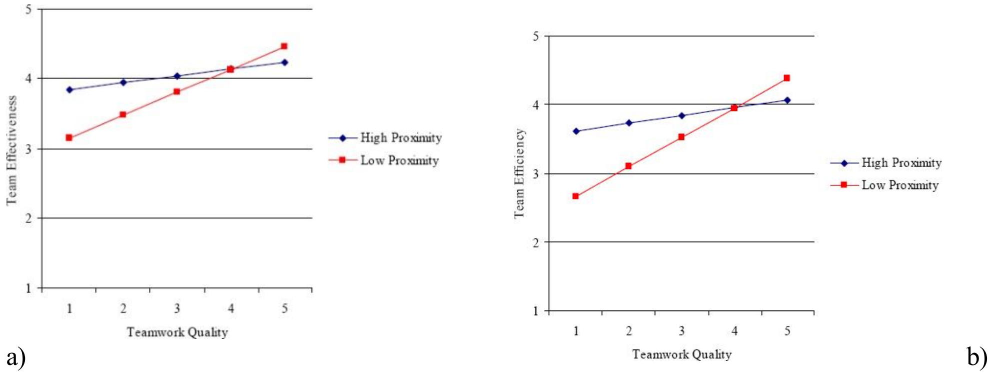

Fig.2. a) Moderation Effect of Team Member Proximity on the Relationship between Teamwork Quality and Team Effectiveness, b) Moderation Effect of Team Member Proximity on the Relationship between Teamwork Quality and Team Efficiency [4]

3. CONCLUSION

Following these steps can help with gaining and keeping your employees respect and them continuing to look up to you as a good leader and boss. If you want to take your business to the next level, this is something you have to place special emphasis on. The employees are the ones who are going to bolster the growth and success of your business through their efforts, dedication and loyalty. Earning their respect ensures you get the best of what they have to offer and that they put their best foot forward for your business. Communication provides a means for the exchange of information among team members. The quality of communication within a team can be described in terms of the formalization, structure, and openness of the information exchange. The degree of formalization describes how spontaneously team members are able to converse with each other.

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-16-0488.

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Machine Modification, Plant Simulation, Production

Marek KLIMENT* , Peter TREBUŇA** , Richard DUDA***

VERIFICATION OF MACHINE MODIFICATION IN PRODUCTION PROCESS WITH SOFTWARE MODULE TECNOMATIX PLANT SIMULATION

Abstract
The paper is focused on the production of components for the automotive industry. It is the production and assembly of components for car doors handles. It describes the assembly process of the individual parts needed for a functional assembly unit used daily by people to open and close the car. In everyday life we do not realize what a difficult process and how all the components needed to perform perfectly normal activity at the car door opening. Every business, whether engaged in the production of products or the provision of services, aims to make everything work as efficiently as possible and to achieve the maximum with the least amount of resources. In improving each process, it is essential to use the tools that are available and achieve the highest degree of efficiency for both the business and the end customer, who often does not even realize what's behind the everyday consumption. Such means are also simulation software and various management methods. We also use these resources to solve problems and shortcomings in the production of our contribution. It is necessary to deal with the life cycle of the product and means that are within him consume and affect the final price. These are products and parts of products, human as well as material resources coming into production processes.

1. INTRODUCTION

The paper deals with the selected production process and production line, which covers this process. It is a manufacturing process for manufacturing car handles and their components. This process consists of several assembly stations. At each assembly station, components are added to the assembly assembly until the final product is finished. The product is subsequently inspected and tested at the test stations and subsequently packaged and the production process is abandoned. We have analyzed the production process and created its simulation using the Tecnomatix Plant Simulation software tool. In the proposal to increase efficiency, we will

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address the possibility of modifying existing machines, reassessing the number of operators and deploying individual jobs. These solutions are further discussed in the following chapters.

2. Description of the manufacturing process and individual assembly stations

The manufacturing process we've been dealing with is the car door handle holder. It's part of the component, which is located between the outer and inner door handles car.
Using the handle holder, the handles are mounted and held together. Handler holders are a very important component in cars because we can use them to move handles. The production line is capable of producing 1,650 pieces for change. The time for making one handle holder is 110 seconds. Every 13 seconds, one finished product must come out of the line. On each post is operator. There are 10 operators on this production line and their number may change as needed. Each component has its specification, e.g. dimensions, appearance, material and the like. This assembly process consists of assembly and testing operations. Assembly operations consist of eight locations where components are connected. The result is a finished product. For assembly operations on individual posts, it is necessary to distinguish left driver and passenger, right driver and passenger.

- Inserting the rubber damper into the counterweight flap,
- Inserting the slider and springs into the counterweight flap,
- Lubrication of the saddle and the insertion of the bowden cable liner,
- Inserting double spring and fixing pins,
- Insertion and lubrication of kinematic slider and pin insertion,
- Inserting and push pins,
- Mounting inerial system,
- Pushing pins into the inerial system,
- Product testing.

Production process simulation
The entire production process was reflected in the simulation using the Tecnomatix Plant Simulation software module. Simulation (Fig. 3) also shows the schematic ground plan of the entire production process and the method of disposition of workplaces.
On the production layout, we can see 12 jobs at each job position. In the chapters above, it has been mentioned that 10 workers serve the line. In the simulation it is possible to see the pathway, after which operators come to the line but also two shorter paths directly at the line. After this, two operators move between jobs to lines and hold 2 posts in the production process.

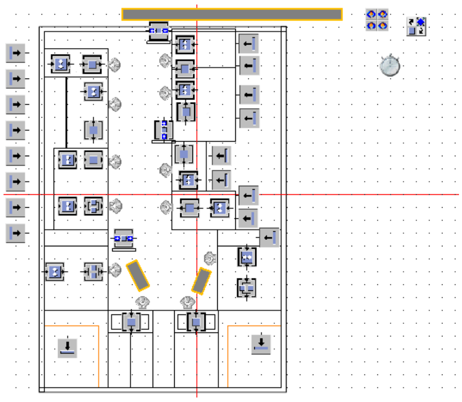

Fig. 1 Simulation of manufacturing process of car door handle holder

3. SUGGESTIONS FOR INCREASING THE EFFICIENCY OF THE PRODUCTION PROCESS BY MODIFYING THE MACHINE

Modification of the machine is a possible way of making the production process more efficient. The term machine modification means that we will modify certain parameters of the machine, resp. we add changes to the manufacturing process that the machine will perform. Modifying the machine would be done by the company that supplied the particular machine. Our goal is to save time on assembly work. Can save time if we merge operations performed on the first and second production station. This proposal can eliminate one operator. The suggestion is that inserting the rubber damper into the counterweight flap will automatically be a machine. When inserting with the help of a machine, there is a risk of misalignment of the rubber muffler. The operator stayed in this undemanding operation for over 10 seconds. By combining these two processes with modification, we can do two operations in 12.3 seconds. We save 13.6 seconds. The proposal can be seen reflected in the simulation of Fig. 4.

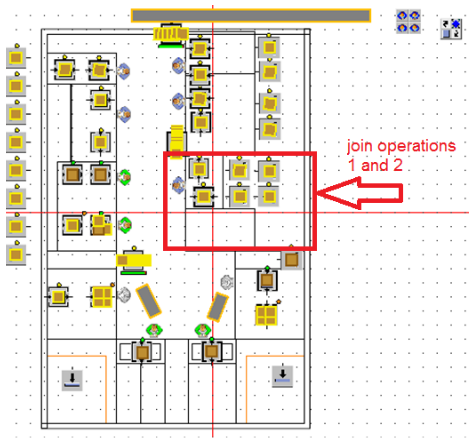

Fig. 2 Suggestion of machine modification in simulation

CONCLUSION

In this proposal, we can see that the process of continuous improvement and efficiency improvement is necessary and justified. By implementing these proposals, society can save a considerable amount of resources on human resources. Modifying of the machine would reduce the need for operators and reduce the number about one worker per workforce per each production change in line activity. Furthermore, the continuity of the production process on the entire line would be improved by redistributing the individual production operations. It also shortened the production cycle time of the product. As a result, there is a growing need to use all available resources to analyze and improve the efficiency of production processes, whether they are software or different management methods that can be applied in a given situation.

This article was created by implementation of the grant projects VEGA 1/0708/16 , APVV-17-0258 , KEGA 030TUKE-4/2017

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Knowledge, Performance, Performance evaluation

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KNOWLEDGE USE IN COMPANY PERFORMANCE EVALUATION SYSTEM

Abstract
The current market state, influenced by globalisation is often marked by the difference between global and local market, company performance and its performance evaluation. The effort to find potential to increase performance has become a part of everyday work of company management in many industrial sectors. Also, last but not least, it is the ability to share and develop knowledge in a company, awareness of the relation between knowledge and performance, between knowledge and ability to measure to influence performance. This is the key factor for the state when the management's effort in a company have a chance to achieve a successful result.

1. INTRODUCTION

There has been a significant globalisation of the world market over the past two decades and competition pressure in slowly developing markets has grown as well. Global competitors use various marketing strategies in order to reach maximum market share, reduction of local producers' impact and their control of market situation. (Kováč, 2008)

The key factor determining company competitiveness is performance.

In general, **performance** can be defined as a company ability to achieve necessary outputs and effects in measurable units if possible (Lesáková, 2004) or in other words, the ability to achieve set targets, evaluate introduced sources with its activity, produce profit, increase the company value and ensure future development (Durkáčová, Kalafusová, 2012).

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Company's performance is not a function of one parameter, it is a function of several parameters and their mutual interaction. Also, the sector in which the company is engaged and what products or services it offers in the market is very crucial. The influence on performance and competitiveness of individual factors is then dependant on this. For example, if there is a company from an automobile industry, providing components produced in hundreds of pieces, then the key factors, significantly determining the ability to have a competitive performance, mean the access to the latest technologies, knowledge management for process setting and company's financial strength. On the other hand, a local manufacturer offering for example services for small-scale manufacturers could be in a position when the latest technology might not be a guarantee of his success but rather an ability to communicate, compliance with agreements, quality of work, people and their knowledge who can balance the lack of access to latest technologies. Therefore, it can be generally stated that people, their motivation and knowledge are the basic presumptions for a company's successful performance.

2. PERFORMANCE EVALUATION

In order to evaluate performance, the company needs to be able to identify what is best for its developement from existentional and agricultural point of view. In general, it is presumed that only something that can be measured and evaluated could be managed. Therefore, measurement becomes the primary presumption for company performance and its management. Performance measurement includes creation of measurable indicators and their use for achievement evaluation of tactical, operational and strategic company goals. Basically, we can say, performance measurement is the base for performance management.

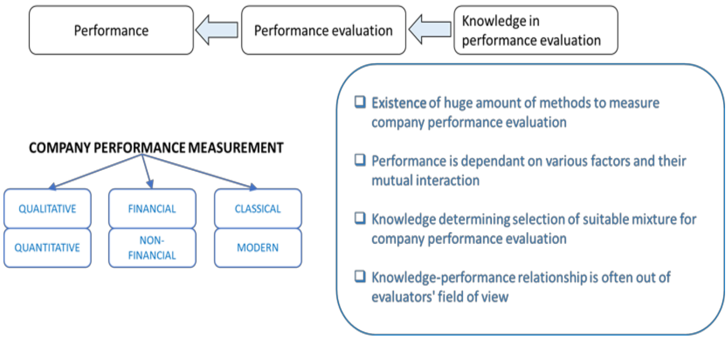

Fig 1. Knowledge influence on company performance evaluation

There is a whole range of methods evaluating various processes and areas of company perfomance when it comes to performance measurement. Knowledge is a key factor in suitable parameter setting for performance measurement. In fact, due to a huge number of methods and parameters, the effort to work and evaluate such wide mixture of performance parameters could be contraproductive. Paradoxically, the effort to generate and evaluate parameters could distract attention and effort from performance increase.In other words, data collection, its processing and recording could become only an aim instead of a state when it is only a tool or foundation for activity increasing performance.It could be concluded, there is a direct relation between knowledge and performance. Even if we considered a state when the processess were ideal at the beggining of company's existence it cannot be guaranteed this state will continue in the next stage. World, cognition, knowledge are constantly developing, that is why a company needs to react to this development. In fact, it is normal people in a company shift between departments or more precisely, come and leave a company if it does not offer share and experience or knowledge exchange and culture supporting knowledge growth.In that case, the company might have serious problems.Archives / banks of successful/unsuccessful solutions are important tools suporting effectiveness and company performance growth.

3. COMPANY – PERFORMANCE-KNOWLEDGE SYSTEM

The figure 2 defines levels of information, knowledge and realisation company processe and expresses mutual interaction between them.

- level of data and information sources: are of external and internal character. They represent information, knowledge and experience potential for a company
- level of company knowledge system: represents a file of methods, techniques and tools used in a certain company
- level of realisation activities: practical realisation of measurement processes, performance evaluation and its increase.

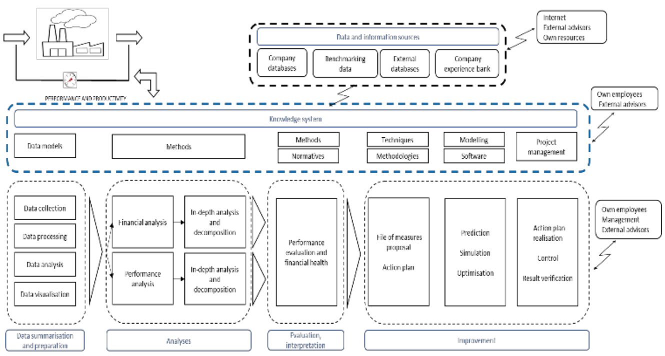

Fig.2 Company performance-knowledge system

All levels are influenced by not only their own employees (internal potential) but by external sources and their potential for a positive change use of company performance.

3.1 Development evaluation and increase diagram of company performance.

There must be a sequence of selected steps kept in the process of company perfomance increase. Incosistent realisation of each step creates a space which quite likely does not need to be improved. If a company does not have correct data or does not have required data, then it is not possible to carry out analyses, and without these we are unable to identify root state causes. In other words, mutual factor and process conditionality determining performance. Correct evaluation and external examination are important for a state awareness and they also determine decisions for next steps.

4. CONCLUSION

The company's ability to identify the level of its knowledge and relation with ability to increase its performance is one of the key factors determining its positive development nowadays. However, in many cases good practice or experience points out that mistakes are already made at the beginning of company performance evaluation - in the stage of data preparation. The introduction of performance evaluation process already defines knowledge meaning as limiting a success factor of an entire file of activities related to company performance increase. Moreover, it is very important to know what data is necessary for a certain type of company and processes. Also, it is importatant to know how to collect them and work with them in the analysis state. This is confirmed by the fact that knowledge and ability of its maintenance, share and developement represent a significant competitive advantage. Furthermore, there has been confirmed that the difference between good and bad companies is in type of information and knowledge and how these can be used in professional life.

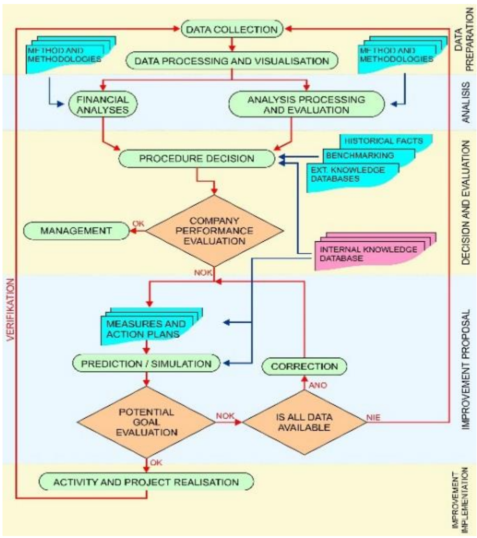

Fig.3 Developement framework diagram of company's performance evaluation and increase, stage illustration with knowledge influence

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Manipulation, Gripper, Plastic Materials, Refractory

Jiří KYNCL, Martin KYNCL, Tomáš KELLNER *

CONCEPT OF MANIPULATION WITH REFRACTORY PRODUCTS

Abstract

Manipulation with variety of products of different shapes and sizes is very common in industry, mainly in highly automated industry segments, such as automotive. These products have one thing in common - they are all rigid. This paper deals with concept of manipulation for raw and semi-finished refractory products. Before firing, refractory products are pressed and extruded into raw blank. The blanks are either fragile or plastic, thus very demanding from the point of manipulation. In this paper, the concepts for manipulation solutions are submitted.

1. INTRODUCTION

Refractory materials are used in industrial high temperature processes to protect kilns and thermal equipment from thermal, chemical and mechanical stresses. Refractory materials are indispensable for the production of iron and steel, glass, cement, aluminium and copper, as well as in the chemical and petrochemical industries, incinerators, and so on. One of the main refractory products are ceramic chimney pipes (CCP). They are used as the main building part of domestic and industrial chimney systems and characterized by high heat and corrosion resistance.

The production of ceramic chimney pipes begins with the preparation of the mixture. The basic components of each blend are dense materials and a binder such as clay. This mixture is brought to the extruder by a conveyor. Then an endless blank is extruded. After extruding the endless blank from the press, the blank is cut and a groove is machined on it. Subsequently, the pipe blank must be dried and fired. Moving to the kiln car is done manually. Manual handling is the main problem because the pipe is deformed in its central part. Further deformation occurs after firing at the end of the pipe due to stacking of the pipes on top of each other. Due to the nature

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of the chimney pipe, the automation of handling is relatively difficult. The pipe is very soft in its raw state, its surface is rough, wet and greasy.

2. APRROACH TO MANIPULATION PROCESS

There are several approaches to designing the end effector. A simple division into two groups, namely a mechanical or vacuum grip of the pipe, will serve for our purposes. The advantage of a mechanical gripper is higher grip reliability. The advantage of a vacuum gripping system is the minimization of the acting force. The disadvantage of this system is the instability of the grip and the possibility of vacuum loss. Creating a risk analysis has shown that vacuum technology is a more suitable option, especially because of the minimal force on the pipe and the high variability of the solution. Another important reason for choosing vacuum handling is the fact that the CCP are highly abrasive and any mechanical manipulator would be prone to failure and would need increased maintenance. It is necessary to design the entire system to ensure stable repeatability, not only through the differences in CCP shape, but also in their rough, oily and wet surfaces and to replace the existing manual method of handling with new technology. This requires among other things the design and selection suitable end effectors.

As the first step, it is important to design and realize the tests of the holding force (load capacity tests) of vacuum elements - suction cups. Normally there are suction cups that are used for handling smooth and clean surfaces such as preserved metal sheets. In contrast, CCP are damp and greasy, rough and oval. The action of external force on the ceramic chimney pipe is not possible without distributing the applied force to the largest possible surface of the raw ceramic pipe - this would lead to cracking. However, the size of the suction cup must not be too large. A device was designed for tests to determine the maximum load-bearing capacity of gripper (fixture) and vacuum elements in the radial and axial directions. On the basis of partial tests, oval suction cups designed for handling greasy sheets were chosen. Subsequently, further tests were realized and appropriate calculations were made. The result is four 90 x 35 mm oval suction cups designed to handle grease sheets that are chosen to design final effectors.

Several end effector designs (grippers) were processed. First, the necessary system requirements were defined: rigidity of the structure, low weight and the ability to handle loads without loss of grip during dynamic movements. [1]

For this reason, gripper prototypes (in parallel with suction test tests) were designed to detect possible deficiencies in the handling mechanism. After successful testing of functional variants it is possible to design effectors for real operation. The second step was to design hand-operated grippers to be serviced by employees. By implementing a vacuum balancer, the employee will require little physical effort. The third and final step was the design of gripping devices for the robotic arm. [2]

The individual design solutions are: prototype effectors - effector with Oval suction cup, steel plate effector, pocket effector; manual effectors - effector for long CCP, effector for short CCP; robotic effectors - effector for short CCP, effector for four short CCP and base ring

3. CONCEPT OF PRODUCTS MANIPULATION

Very important aspect for the whole concept of manipulation is the dividing of manipulation for low turnover and high turnover products. The manual handling device for low turnover production utilizes the single-purpose machine itself and the manual vacuum manipulator provided with the above-mentioned effectors. In contrast, robotic arms built into the automatic production line will be used for high turnover products.

The handling equipment for low turnover production consists of a manual handling device and a vacuum manipulator equipped with effectors. Vacuum is supplied by a range of ejectors. The handling process begins by removing the CCP blank from the conveyor (after extrusion and cutting) using this device. The empty CCP is then moved to clean the material residues after cutting. Another position of CCP blank is in a device for forming a sealing element - usually referred to as a tongue and groove. The finished raw pipe is then moved to the final position, where it rotates to a vertical position. The worker removes the finished raw pipe from the end position with the manipulator and the vacuum balancer and places it on the drying car. The proposed solution consists of standardized parts and therefore it is not a large investment. Fig. 1 shows a model of a semi-automatic manipulation system. [3]

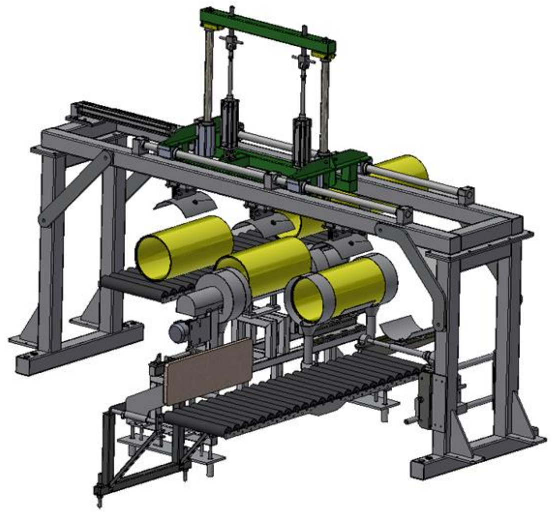

Fig. 1. Design of semi-automatic manipulation system

Another handling system was chosen for high turnover production. After extrusion, the pipe is extruded and moved to the first (smaller) robotic working space. By the first robot, the pipe blank is removed from the conveyor by the gripper and manipulated to the stacking location. Then the robot returns to the position to pick up another pipe. As soon as 3 to 4 pipes are placed at the stacking location, the other robot comes forward. This second (larger) robot with large gripper immediately picks up all the pipes (and the base ring) and moves them to a predetermined target position on the surface of kiln car (see on Fig. 2). During this manipulation, the limitations of automation are the weight of the manipulated assembly and the maximum range of the robot required to place the assembly in the furthest corner of the kiln car. [3,4]

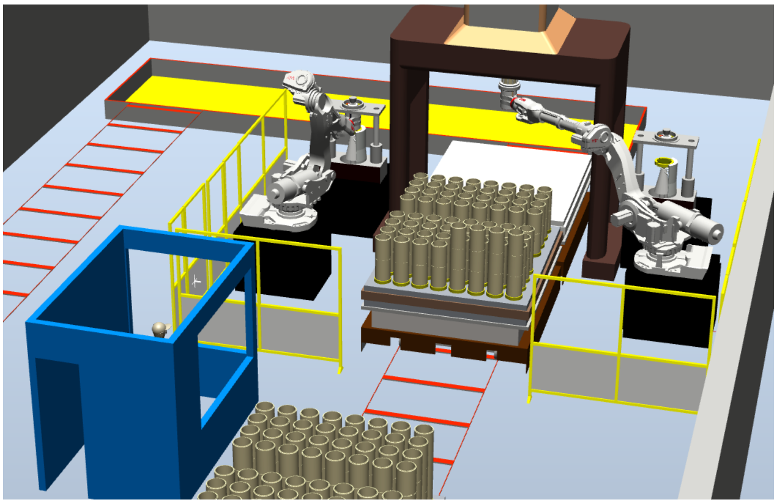

Fig. 2. Design of automatic manipulation system

4. CONCLUSION

The main aim of this paper is design a technology for handling system. This paper deals with design solutions for handling raw ceramic pipes. CCP Handling, CCP Load Testing, and Handling System Design (CCP) have been realized. The designed prototype effectors were used for static load tests, and the optimal variant of the effector was selected based on test results and calculations. A large suction cup for handling the oily surfaces is used. All four gripper variants were tested with all the requirements for handling the chimney pipes without undesirable deformation of pipe shape and surface. A semi-automatic system using a manual handling device together with a vacuum manipulator was designed for the low turnover dimensions of pipes. For more frequent chimney pipe sizes, the two robotic arm automatic handling system is designed to maximize process productivity and shorten production line tact. This demands the high quality of the handling system, especially on the grippers and the quality of the suction elements.

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Maintenance, Ergonomic, Energy expenditure

Marta POMIETLORZ-LOSKA*

DESIGNING HUMANIZED FORMS OF WORK ORGANIZATION ON THE EXAMPLE OF THE MAINTENANCE DEPARTMENT

Abstract
This article refers to the subject of ergonomic organization of the workplace. Presents the characteristics of the maintenance department. The main purpose of the article is to present the ergonomic aspects of new forms of work organization on the example of employees of the Maintenance Department. Presentation of the measures of the assessment of working conditions, mainly assessing safety and comfort of the work.

1. INTRODUCTION

The ergonomic aspects of designing specific organizational solutions focus on the identification and implementation of elements, factors and remedies that aim at comprehensive adjustment of work to people. Complexity is understood as ensuring the highest level of ergonomic quality of work, taking into account possibly all technical and organizational factors and material factors of the work environment occurring in a given position. But above all, the possibilities, limitations and needs of the employee [1].

The growing complexity of production systems and advanced technological solutions put high demands on specialists in the maintenance department. Due to the continuous process of improving machines and devices, which is largely associated with the dynamic progress of automation, as well as the constantly growing expectations from industry, ensuring effective operation of the maintenance department becomes the strategic goal of the company [2]. The main purpose of the article is to present the ergonomic aspects of new forms of work organization on the example of employees of the Maintenance Department. Presentation of the measures of the assessment of working conditions, mainly assessing safety and comfort of the work. Research methods to meet the basic purpose of the article are desk research and physical and psychological stress tests of the employee using Body Media Sense Wear.

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2. ERGONOMIC ASPECTS IN THE AREA OF NEW FORMS OF WORK ORGANIZATION

The basic postulate related to ergonomic design and organization of work is the so-called humanization of work, the aim of which is to make forms of work organization more flexible. Ergonomic organization of work is related to [1]:

- human participation in the work process in accordance with its physiological rhythm,
- psychophysical needs of a given employee,
- an appropriate choice of working methods,
- providing the employee with appropriate breaks while working,
- avoiding work at night (shift work aspect),
- organizing work in a system of flexible hours,
- ensuring high quality working conditions based on order standards,
- job valuation.

In order to measure the efficiency of the organization of ergonomic aspects in the area of work, a full range of measures for the assessment of working conditions is used, the most commonly used in industrial practice is [1]: assessment of staff liquidity (employment fluctuation, internal and external liquidity), evaluation of work safety, assessment of accidents at work, risk assessment, assessment of effects at a given employee, assessment of work efficiency, assessment of technical equipment at work, economic evaluation of ergonomic solutions (productivity index, payback period).

3.CHARACTERISTICS OF THE MAINTENANCE

In the light of EN 13306: 2010, maintenance is defined as follows: "a combination of all technical, administrative and managerial activities during the lifecycle of an object, aimed at maintaining or restoring the state in which an object can perform its functions" [3].

Based on the analysis of the literature on the subject, it can be concluded that a frequently observed thesis assuming the fundamental goal of the existence of the Maintenance Department is to optimize the availability of devices at a minimum cost. Of course, this approach at the turn of the years evolved and nowadays maintenance is defined much more broadly, because it also includes in its scope the safety of people and the environment, production efficiency, risk level, effective energy consumption, as well as the quality of products and services [4]. „In large organizations, production became the responsibility of area or product managers, who must react quickly as economic conditions change. Management participation and job enrichment for frontline workers improved productivity and effectiveness. Especially in larger organizations, structure shifted toward decentralization, and maintenance moved into the mainstream of operations. In some organizations, the maintenance manager completely disappeared and was replaced by production area superintendents" [5]. Characteristics of duties at the workplace of specialists in the maintenance department is connected with activities that generate a certain level of physical workload. Along with physical exertion, energy changes take place in the human body, which constitute the area of research, related to the assessment of the workplace in terms of physical work load. Rating of the so-called The energy cost, when employees perform specific professional activities, is elementary for the correct (ergonomic) shaping of working conditions.

Energy expenditure, on the other hand, is the basic measure that illustrates the workload of an employee at a selected workplace [6].

4. URGENESS OF WORK OF WORKERS OF THE MAINTENANCE DEPARTMENT

Considerations about the onerousness of work should begin with defining the term nuisance / harmful factor. According to the Chief Sanitary Inspector - a nuisance factor in the work environment is a factor whose impact on the employee may be a cause of bad mood or excessive fatigue. It does not pose a threat to human health or life, but it significantly contributes to lowering its ability to perform work or other activities or reduces efficiency [7].

Methods for assessing energy expenditure in connection with physical workload, which find application in work physiology, are mainly related to measuring changes, their dynamics and various parameters of the human body in the time performed by the worker, namely [8]:

- energy expenditure defined and described earlier - including the assessment of its size,
- examination of changes in the muscular system - analysis of muscle fatigue, made, for example, using a dynamometer or ergo graph, or recording of muscle currents, i.e. the so-called electromyogram,
- observation and examination of the respiratory system - mainly based on the measurement of the dynamics of respiratory parameters such as respiratory rate, increase in minute lung ventilation or O2 consumption,
- price of changes taking place in the central nervous system of the brain,
- analysis of the circulatory system - involving the observation and measurement of changes in hemodynamic parameters: the ejection volume of the heart, blood pressure or increase in the pulse rate.

The methods used to assess the physical workload include [1]:objective measurement methods: direct and indirect calorimetry, motion detection and recording, and physiological methods; subjective methods of measurement, which can be divided into two main types, namely timing and tabular methods and questionnaire methods.

Own research related to the workload of an employee of the Maintenance Department is the measurement of selected parameters of physical activity, using the Body Media Sense Wear equipment that has been presented. The tests included the first shift in the cycle of an 8-hour working day. The obtained results were averaged. Physical load, expressed in the form of energy expenditure, allowed to qualify the work in terms of its severity.

On the aspect of nuisance of work, the elementary influence is, among others, the structure of the expenditure, i.e. the occurrence of load unevenness, above all the activity that requires maximum effort. Unevenness of the workload is related to the specificity of the work of employees of the Maintenance Department. Their work depends, among other things, on the number of failures and stoppages of the machine park, ergonomic quality of work organization in connection with current activities and preventive activities.

The nuisance of the work of maintenance workers is also related to the assumed body position and severe conditions, lighting in the workplace - during intervention in robotic production sockets.

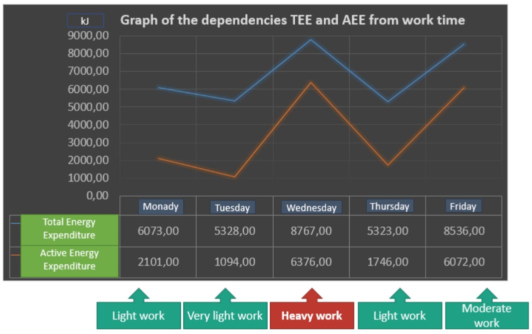

Fig.2. Relation between energy expenditure and workload

5. CONCLUSION

To sum up humanization of work organization is aimed at adapting work to human capabilities. In addition to the technical and economic criteria, the constructor of the machine must also consider ergonomic criteria. The organization of work is related to ensuring proper balancing during work tasks. Thanks to the analysis of the employee's workload, the person managing the Department, eg. Maintenance, is able to plan the employee's work with all possible work standards. The energy cost of a UR employee is incomparable, in relation to production employees, where one can observe the repeatability of movements and time norms related to the work process. In the Maintenance Department, a very useful tool for the diagnosis of workload is the schedule of preventive work and intervention card, because then you can identify the employee's professional activity with the energy he expended.

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THE INFLUENCE OF SENZOR POSITION ON AGV DRIVING PROPERTIES

Abstract
Nowadays manufacturing and logistics systems are focusing on improving their processes by implementing autonomous systems. The one of the most applied systems in manufacturing logistics are Automated Guided Vehicles. This article focuses on improving driving properties of AGV by finding suitable pitch and ejection of three sensors along with line thickness and minimum path radius.

1. INTRODUCTION

Industry 4.0 requires deployment and logistics 4.0. It requires the deployment of automated traffic. AGVs can provide internal automated transport. The AGV can be navigated with a black tape on the floor or lasers [1].
The simplest AGV is controlled by the black tape and the sensors only have to detect the edge of a line. Multiple sensors or scanner systems can be more complex, see Fig. 1 [2]. A superior stage is the orientation in space by laser and reflectors [3].

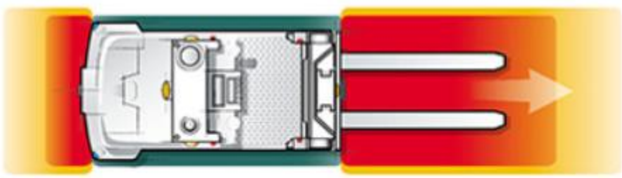

Fig.1. AGV with scanners [2]

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The AGV used in the research is oriented in space with the aid of a black tape. The smoother the AGV moves, the less vibration the AGV has. In this way, it moves even more smoothly and transports the transported material in the required quality with the right speed. At the same time, the truck will be able to arrive more precisely at the destination station.
Used wheelchair, see Fig. 2, has two drive wheels with a pitch of 135 mm and one support wheel. The drive wheels provide different turning speeds. Three sensors are used for driving. The middle sensor detects the line and monitors leaving the runway. The side sensors detect a logical value of 0 and 1 of the line edge.

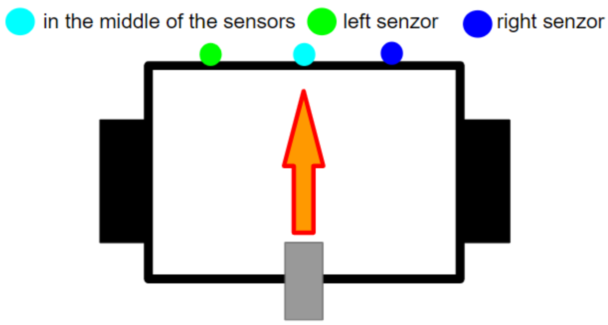

Fig. 2. Used AGV

The research deals with the influence of input parameters on the characteristics of driving properties. The input parameters are position of the sensors and the shape and thickness of the black tape. Property driving characteristics is based on the minimum required AGV radius so that the track passes without running off. The AGV moves either straight or turns by defined radius. The purpose function is equal to a defined turning radius so that the AGV does not exit the track.

2. DRIVING PROPERTIES EXPERIMENT

The analysis is performed in Matlab computing program. The track consists of 30 arches of the currently tested radii. The following flow diagram is used for control logic, see Fig. 4. Where "S" = Straight, "L" = Left, "R" = Right.

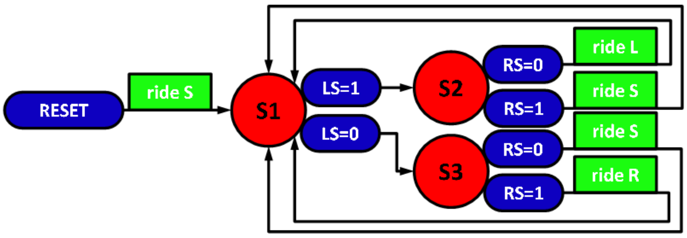

Fig. 4. Control logic

The AGV goes straight if both sensors are logical values 0 or 1. The AGV turns left if the left sensor is in logic 1 and the right sensor is in logic 0. On the contrary, it turns right if the left sensor is in logic 0 and the right sensor in logic 1.
The research deals with the influence of input parameters on the characteristics of driving properties. Parameter experiments are presented in these settings: step = 1 mm.

- Line thickness: 10 and 80 mm.
- Path radius in curves: 200 and 1000 mm.
- Right and left side sensor spacing: from 50 to 150 % of the line thickness in 15 settings.
- Ejecting side sensors: 30 up to 100 mm in 15 settings.

There are four graphs in total, each with 225 tests.

3. RESULT

Two track radius parameters and two line thicknesses were tested. Testing was performed for sensor spacing from 50% to 150% of line width and sensor extrusion from 30 to 100. Greater driving smoothness occurs with a larger travel radius, as the AGV is less oscillating left and right. At the same time, the greater the ejection, the more sensitive the change of direction of the truck. The resulting diagrams are displayed in Fig.5. and Fig.6.
Diagram Fig.5.a and Fig.5.b have the same track radius of 200 mm. Greater fluency will be achieved with greater line width and with sensor spacing greater than line thickness. Diagram Fig.6.a and Fig.6.b have the same track radius of 1000 mm. Greater fluency will be achieved with less line width and sensor spacing equal to line width.

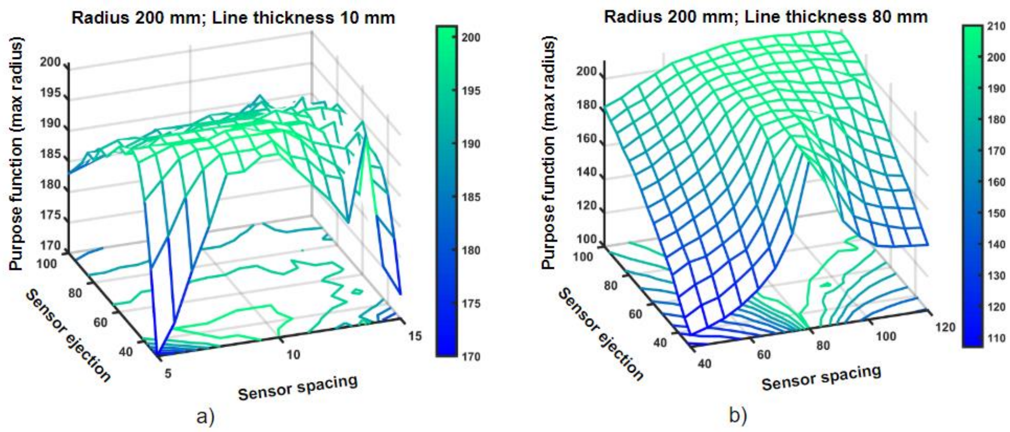

Fig.5. Resulting graphs – radius 200 mm

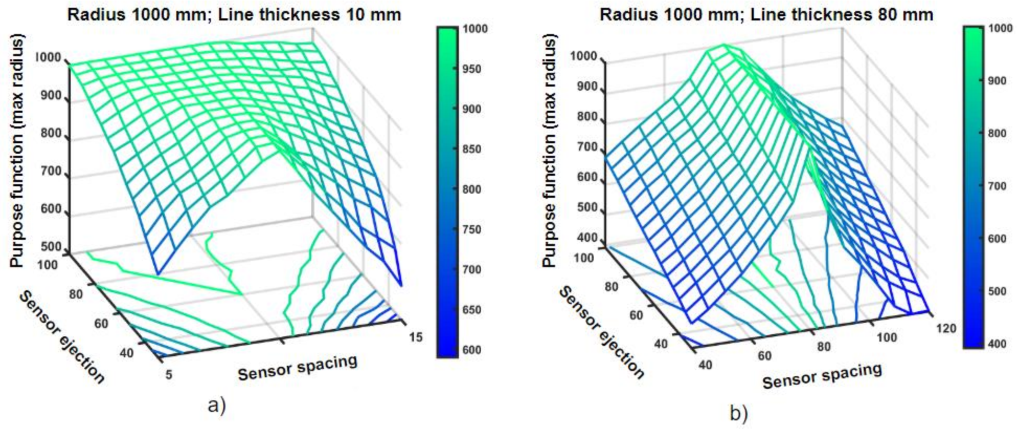

Fig.6. Resulting graphs – radius 1000 mm

4. CONCLUSION

The smaller the radius of the track, the more advisable it is to choose a wider track line. A track with radius of 200 mm and a width of 80 mm was tested. For this, it is recommended to select the sensor spacing at least corresponding to the line width, rather larger. For large radii of 1000 mm or more, it is advisable to select a thin line width of 10 mm and the sensor spacing ideally equal to line width. For the ejection it is suitable in all cases to be larger, i.e. 80–100 mm.

This publication was written at Technical University of Liberec as part of the project (21278) – "Optimization of manufacturing systems, 3D technologies and automation" with the support of the Specific University Research Grant, as provided by the Ministry of Education, Youth and Sports of the Czech Republic in the year 2018.

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Reconfigurable Manufacturing Systems, Warehouse Layout, Modular Platform

Martin MARSCHALL*, Branislav MIČIETA**, Radovan SKOKAN***

LAYOUT OF WAREHOUSE OF MODULAR PLATFORMS IN RECONFIGURABLE MANUFACTURING SYSTEMS

Abstract

The new requirements in production require new approaches for designing production systems. Reconfigurable manufacturing systems that are able to quickly change the layout of production modules and quickly adapt to the production of the new product is one of these approaches, which can meet new demands on quick adaptation on new demands. As a part of reconfigurable manufacturing systems, layout of warehouse of modular platforms has high impact on reconfigurable manufacturing systems performance.

1. INTRODUCTION

In the last few decades, new production requirements have arisen, and new requirements have not been met by traditional production systems. Reconfigurable manufacturing systems are one of possible manufacturing systems, which can fulfill these new requirements.

Reconfigurable manufacturing systems consist of more subsystems, such as control system, mobile robotic system, modular platform, superstructure, layout manager, power management system and warehouse of idle modular platforms. Each subsystem is able to affect the performance of whole system.

Reconfigurable manufacturing line is a modular line, which is built of separate manufacturing modules – modular platforms. Modular platforms, which are necessary to produce a required product are moved to production area to create a manufacturing line and idle modular platforms are moved to storage area – warehouse of modular platforms. Layout of this warehouse can affect the performance of reconfigurable manufacturing system. It has greatest impact on reconfiguration time, which is time necessary to assemble new production line from idle modular platforms in the warehouse.

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2. POSSIBLE LAYOUTS OF WAREHOUSE OF MODULAR PLATFORMS

There are four basic ways to consider when designing a possible mobile platform warehouse layout:

- single-row distribution of modular platforms,
- multi-row distribution of modular platforms,
- multi-row distribution of modular platforms with access corridors,
- multi-row distribution of modular platforms based on platform type.

2.1 Single-row distribution of modular platforms

This layout consists in placing unused modular platforms in one row at the edge of the production area.

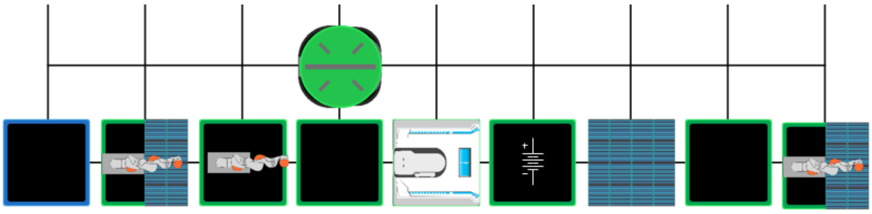

Fig. 1: Single-row distribution of modular platforms

The main advantage of this solution is the easy access of the mobile robotic system to each of the available modular platforms. However, in case of more unused platforms, there is an increased demand for dedicated storage space for modular platforms because unused platforms can only be stored at the edges of the production area. In the case of the deployment of unused platforms in other places, the time needed to reconfigure the production line could be prolonged due to the need to circumvent idle platforms located in production area.

2.2 Multi-row distribution of modular platforms

Unlike the previous design, in this case it is possible to store idle modular platforms in multiple rows. The advantage of this solution is the possibility to place the unused platform on the nearest available space in the warehouse. It is also possible to concentrate all idle modular platforms in a dedicated space and eliminate the need to place them only around the perimeter of the production area.

In the case that only modular platforms from the outer row are used to create a new manufacturing line, this warehouse layout design shows the same results as the previous single-row solution. However, when using platforms from inner rows, there is a significant increase in the time it takes to get the platform from warehouse because of the need to move platforms in front of the needed platform and then return the moved platforms back to storage area.

2.3 Multi-row distribution of modular platforms with access corridors

With this storage space solution, every second position is occupied, and there is a blank space between the occupied positions to provide easy access to all stored modular platforms.

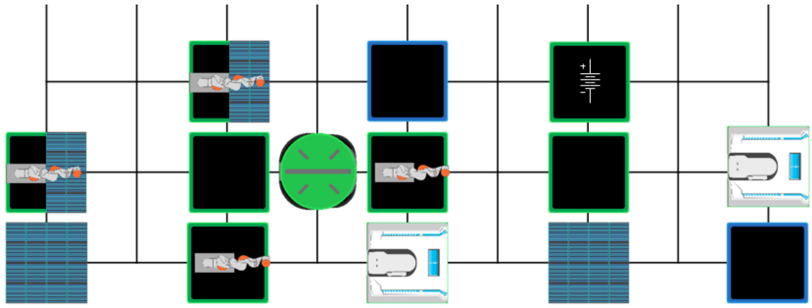

Fig. 2: Multi-row distribution of modular platforms with access corridors

The advantage of this solution is easy access to all platforms and the ability to place idle platforms outside the perimeter of the production area. Due to the creation of corridors, however, compared to the multi-row random distribution of modular platforms, the dedicated storage space must be bigger than in the warehouse with multi-row distribution of modular platforms.

2.4 Multi-row distribution of modular platforms based on platform type

This solution involves placing the same type of platform in one column. With such a layout, direct access to any type of modular platform is possible without the need to move other platforms. The layout also eliminates the need for access corridors and thus reduces space requirements for storage space.
This solution is particularly beneficial in reconfigurable manufacturing system with lower number of modular platform types. However, in the case of increased number of unique, specialized modular platforms, the size of the dedicated storage space is increasing and its inefficient use occurs.

2.5 Combined modular platform layout solution

This case is a combination of multi-row distribution of modular platforms based on platform type and multi-row distribution of modular platforms with access corridors.

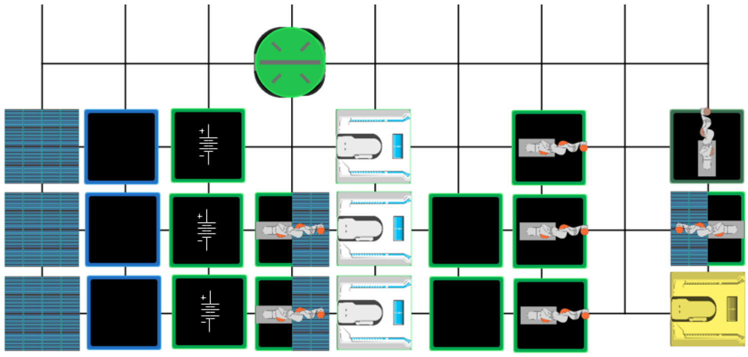

Fig. 3: Combined modular platform layout solution

The solution combines the advantages of these two previous solutions. Recurring modular platforms are stored in a column based on their type. Unique specialized modular platforms are stored on the side of dedicated warehouse space with an access corridor created by free space between columns. This solution lessens the demand on size of dedicated warehouse area, and it allows easy access to each type of modular platform.

3. CONCLUSION

Layout of warehouse of modular platforms can greatly affect the performance of reconfigurable manufacturing systems during the process of reconfiguration. To achieve the shortest possible reconfiguration times, it is necessary to choose the best layout based on actual production area and on number of unique types of modular platform. The main point is to lower the demands on warehouse size and to allow direct access to each of modular platform types. When these two conditions are met, warehouse influence on the reconfigurable manufacturing line performance is the lowest.

This article was created with support of project: KEGA 022ŽU-4/2019

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Industrial engineering, Cooperative robot, Assembly process

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HUMAN-ROBOT COOPERATION IN ASSEMBLY PROCESS

Abstract
The action of human and the robot has its advantages in the assembly. The benefits of a human include immediate response to problems, flexible responses to changes, and complex assembly activities. The advantages of the robot are that it can perform repetitive and monotonous activities for longer periods without getting tired. The combination of these advantages creates a common workplace in which human and robot cooperate. The paper describes a cooperative robot, its advantages, security and new trends.

1. INTRODUCTION

Industrial production is currently undergoing changes that will shift the focus of production and related research and development, to increase flexibility and responsiveness to production processes, equipment, and entire production networks. The main advances in these changes are reflected in the key goals of reducing downtime and increasing customization, leading to greater diversity and frequent changes in products, components and tasks to be addressed within the same production unit. [1]
Due to the increasing complexity of the products, along with the higher proportion of product integration modules, a change in physical requirements can be applied. Innovative assembly technologies are needed in this context to increase productivity and maintain market competitiveness. Great attention is paid to alternative assembly concepts that can meet the flexibility requirement. Through the effective synthesis of human and robotic capabilities, workplace sharing concepts based on collaboration between people and robots offer an adequate combination of individual strengths, which presents enormous potential for cost-effectiveness and flexibility. [2,3]

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Robot and human cooperation aim at relieving the demanding, often repetitive, and dangerous activities that workers perform in the assembly process. When these activities are taken over by robots, quality is assured and ergonomic working conditions are improved. This would allow the worker to focus on activities that require special skills (sensorimotor skills, creative problem solving). [2,4,5]

2. COOPERATIVE ROBOT

A cooperative robot (cobot) is a mechanical device in assembly cells (hybrid assembly) that manipulates objects in direct collaboration with humans. The cooperative robot helps with complex tasks that cannot be fully automated. For example, they can deliver components to workers who perform more accurate assembly-related activities. The anticipated benefits of using a cooperative robot are increased productivity, improved workplace conditions in terms of ergonomics and safety. Currently, cooperative robots are also referred to as ergonomic cooperative robots due to the application of ergonomic principles to their design (Fig. 3). These changes in the design ensure that no human injury occurs during physical interaction with the robot, or damage to the cooperative robot itself. Cooperating with a human being, a cooperative robot helps a person with challenging, repetitive and complex activities, protecting the worker from health problems and work injuries. [4,5]

2.1 Cooperative robot in terms of ergonomics

It was not necessary to consider ergonomics in the production of traditional industrial robots because they were not intended for direct human interaction. In the production of cooperative robots, it had to be thought that the robot would physically communicate with the human. There are several ways to build cooperative robots for ergonomics:

- **Change design elements:** rounding edges, covering joints, and removing places that could cause human injury. Rounded gaps (a gap on the cooperative robot's arm) on cooperative robots are designed large enough to fit a human's hand. This eliminates the clamping point, thus avoiding injury.
- **Gravity compensation:** some cooperative robots (e.g. Baxter) can be programmed physically by moving their hands. Without gravitational compensation (servo motors that facilitate the movement of the arms of the robot), this could be strenuous for man in the long run, due to the weight of the shoulders and the complexity of moving with them.
- **Contactless Control:** One way to reduce mechanical stress from setting up a robot is to use a contactless setting. This is because the robot follows the movements of a person and sets the necessary movements, or the robot can be controlled by gestures. The technology described is still under development. [5]

2.2 Cooperative robot in terms of performing human activity

As mentioned in the introduction, another part where the impact of the robot and human cooperation in the hybrid assembly can be observed in terms of ergonomics is in separate activities performed by the robot. It is ideal for a robot to perform repetitive movements that cause human cumulative traumatic distress (CTD) and other injuries. The reduction of human injury in terms of ergonomics has a positive impact on productivity and shows the advantage of robot-human cooperation. [5]

2.3 Security of Cooperative Robot

It is important to ensure safety in hybrid assembly, human-robot collaboration in a common workspace. In order for a robot to cooperate with humans, it must meet the criteria:

- **Robot Security Zone Monitoring:** The area around the robot is divided into two security zones. When a person enters the first security zone (human-robot cooperation zone), the cooperative robot reduces its speed. In the event of a person entering the second zone (interactive workspace for collaboration), the robot stops immediately to avoid any human injury. When a person leaves this zone, the cooperative robot continues to work. Security Zones provide sensors and a 3D camera system that scans the area in real time.
- **Manual robot control**: control the robot under direct operator control.
- **Reducing the power and strength of a robot:** if there is a collision with a human, the robot will reduce its power to a negligible value when in contact with a person. This is achieved by integrating the force and torque sensors, the lightweight design of the individual parts of the robot and the low speed of the robot. [4]

3. NEW TRENDS

New trends in cobots focus on the following areas:

- **Robot programming** – one of the robot programming methods is described in section *3.1 Cooperative Robot for Ergonomics (Gravity compensation)*. This way the operator grab the robot arm and moves with the arm. These movements create a trajectory, after which the robot will move without the operator having to write a line of code.
  Another way of programming is in virtual reality. With VR goggles and hand controllers, the robot learns in virtual reality the movements that are simulated and then are embedded in the real robot.
  The advantage of this programming is the shorter installation time because companies are able to easily program the cooperative robot.
- **Robot intelligence** - so robots can work with humans and be flexible are equipped with different sensors. If we want the robot to analyze the data and to decide, the robot needs improved processing or brains. Robot manufacturers are beginning to use of AI and machine learning. Intelligence is embedded directly into the robot or embedded in an external computer.
- **Robots sensing the world in 3D –** the robot to be more flexible should be equipped with human-like vision. At present, robots are equipped with 2D cameras but only provide a flat projection. 3D cameras are needed to see and work in the three-dimensional world.

Advances in deep learning algorithms combined with powerful hardware (gaming graphics cards) and 3D cameras open up a range of new possibilities in robotics and machine vision. The example of this combination is picking and placing material that is randomly organized (in containers, boxes, shelves), while the collaborative robot can select material to recognize whether the material is defective (quality control) and solve the problem (put it into another box). When performing the pick & place operation, the robot learns which grips work best over time, these grips improve. [5]

4. CONCLUSION

At present, the robot works as a man in a separate workplace. In terms of safety, the robot's workstation is separated by a protective cage and in the case of human entry into the robot's work area, the robot must first stop to avoid injury.
Cooperative robots are beginning to emerge in the marketplace, working together with people in the same workplace. The advantage of collaboration between a robot and a human is that a cooperative robot performs activities that can cause human health problems (repetitive activities) or activities that can injure a person (handling hot or sharp pieces).
When designing cooperative robots, safety must not be forgotten either. That is why designers used ergonomic principles to design cooperative robots. Cooperative robots are also equipped with sensors and a 3D camera system that scans the robot's surroundings in real time to avoid human injury. [6]
New trends in the field of robots are different ways of programming, whether in the virtual reality or by the movement of the robot arms by the operator. Here, too, is the connection of robots with artificial intelligence and the use of 3D cameras for object recognition. As a result, the robot can pick the material, control the material cavity at the same time, and learn to grasp the material best.
An area of exploration in the future could be to combine new collaborative robot trends with AGV carts to create a mobile robot. This mobile robot would be used in the assembly process in the event of an unplanned absence of the installer (health problems).

This article was created with support of project: KEGA 022ŽU-4/2019

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Advanced industrial engineering, Manufacturing buffer, Simulation statistic

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THE USE OF THE STATISTICAL RESULTS OF TECNOMATIX PLANT SIMULATION FOR THE PURPOSES OF DETERMINING THE OPTIMUM MANUFACTURING BUFFER CAPACITY

Abstract
A simulation detecting downtimes of the manufacturing line belongs to the indicator that shows how effective are supplied individual production processes which have a certain height of availability and Mean Time To Repair (MTTR). The factor of the production system including manufacturing buffer capacity (MBC). From the simulation models, it is possible to obtain statistics that are used for the calculation of the optimal MBC. The article contains a description of Tecnomatix Plant Simulation statistic tools from which we get statistic results for the purpose of determination of the optimal MBC.

1. INTRODUCTION

A prerequisite for active reduction of work-in-progress is an effort to find reserves in the system that cause by oversizing ties of capital. Among the places where it is possible to encounter such phenomena include the interoperation manufacturing buffers area. The main task is the creation of such a volume of stock that optimal covers the needs of the workplace for manufacturing buffer in case of previous workplace failure. To assess the impact of the manufacturing buffer capacity (MBC) on the system is possible to use the measurement of the level of downtime and the average number of pieces stored in manufacturing buffer. In their surveys, we can also use some of the simulation tools. The ideal tool for the detection of downtime and the number of pieces is Tecnomatix Plant Simulation. It is a software tool that allows modeling, modeling, analysis, visualization, and optimization. With its help, it is possible to obtain the value of a

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gradual implementation of experiments obtains parameters based on single factor optimization. The subject of the article is a description of the Tecnomatix Plant Simulation software tools that can be used in designing the optimum manufacturing buffer capacity.

2. MATERIAL AND METHODS

The problem of determining the correct simulation of downtime of the production line and the number of pieces is closely related to the quality of the input data. These are sourced from corporate databases, various collection devices or from paper forms. The data that will be analyzed for a sufficiently long time series of the must. In enterprises in the analysis of data, it is possible to encounter with the annual length series on which can be implemented the observation of the trend of downtimes on the machines. The ideal case is the sluggish trend when it can be considered as stable parameters of downtimes. In the case of an increasing or decreasing trend can compensate for this trend is the appropriate distribution. [2] The scheme shown in the diagram below is used for the detection of the optimal MBC. Contain this algorithm is also part of the determined average year MBC and coefficient of downtime (Kp). Currently, this block is dedicated to the third chapter of the article. The algorithm for determining the optimum production capacity of storage shows Fig. 1.

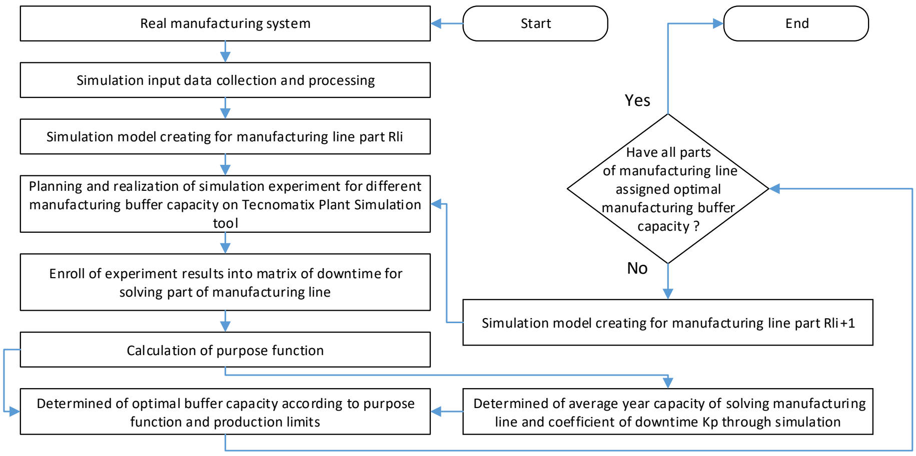

Fig.1. Algorithm for determined optimal manufacturing buffer capacity

The ideal to look optimal MBC is looking near the area of the original normal capacity without regulation the MBC [1]. In solution, however, is to be considered the production limitation that is identified with a simulation or the displacement limit of MBC. We can achieve optimal precious of results if we combine the function of conveyor and manufacturing buffer together. It allows us to make it clear how to manage simulation model of the production line, responds when we change the factor of MBC. Many of the grinding assembly lines fulfill the role of manufacturing buffer just conveyors. If a simulation model contains the conveyor and manufacturing buffer there will not occur change that can be correctly asses.

3. THE USE OF THE STATISTICAL RESULTS FOR THE PURPOSES OF DETERMINING THE OPTIMUM MANUFACTURING BUFFER CAPACITY

Average year manufacturing buffer capacity

For the purpose of obtaining information about how much the proposed solution is more appropriate than the current one, it is necessary to obtain information about the current state of the average of MBC. The current MBC is also used for the determination of the coefficient of downtime (Kp) for given MBC. To obtain this information is used tool "Chart" which is defined to observe conveyor in the function of manufacturing buffer. It is also necessary to set the "Occupancy" so we can see the percentage of the quantity of manufacturing buffer during the reporting period.[3] The result is a graph from which it is possible to obtain information Fig.2.

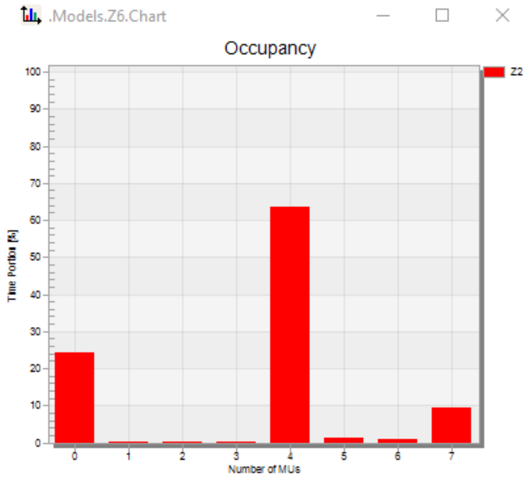

Fig.2. Chart of occupancy for determined average year manufacturing buffer capacity

From Fig. 2 it is possible to read off that 0 pieces are spent in a conveyor belt for 24%, 4 pieces 63%, 5 pieces 2 %, 7 pieces 10%, if the output was 3080 pieces then 24% is 739.2, 63% is 1940.4 pieces, 2% is 61.6 pieces,1% is 30.8 pieces 10% is 308. The pieces are then multiplied by the assigned number (739.2 * 0 + 1940.4 * 61.6*4 + 30.8*6 + 308 * 7)/3 080 = 3.36. If the number comes out, for example 3.36, it roundup to 4 pieces.

Obtain the average downtime of the manufacturing line

The statistics that are in the calculation of the optimal MBC must tend to be related to the last machine or workplace of the system because all the failures of the previous machines will be reflected on the last machine. Statistics about the downtime can be obtained after the end of a simulation run in "Resource statistics" in "Portions of the States ' Fig. 3. a specific indication of the "Working".

Object	Working	Set-up	Waiting	Blocked	Powering up/down	Failed	Stopped	Paused	Unplanned	Portion
A3	75.20%	0.00%	2.66%	0.00%	0.00%	22.14%	0.00%	0.00%	0.00%	

Fig.3. Chart of occupancy for determined average year manufacturing buffer capacity

The coefficient of downtime is obtained through the formula:

$$Kp = 100 - \text{working} \quad (1)$$

From fig. 3. it is possible to find out that the Kp value is 24.8%. Downtime is recorded into a matrix of downtime from there is possible for each to determine the purpose function and optimal MBC. An example of such a filled table shows Fig. 4.

Z2 \ Z1	0	2	4	6
0	27,97%	26,80%	26,00%	25,42%
4	25,61%	24,80%	24,26%	23,86%
5	25,26%	24,52%	24,05%	23,69%
6	24,95%	24,28%	23,89%	23,54%
7	24,68%	24,07%	23,69%	23,40%

Fig.4. A table of information about the value of downtime according to manufacturing buffer capacity

4. CONCLUSION

Tecnomatix Plant Simulation software allows you to retrieve such important statistics which are enough precious to be fit for the calculation of the optimal MBC. On the basis of the observed statistics enroll in the matrix of downtime and current MBC value, it is possible to choose the lowest value of downtime. This value is compared with the production manufacturing line limits find out from the first simulation run. Consequently, is through Kp computed purpose function for all state of MBC. After computing, all purpose function for each MBC is choose MBC with the highest value. The highest value indicates the MBC when a work-in-process is most optimal, and the total cost on work-in-process is the lowest.

This article was created with support of project: KEGA 020ŽU-4/2019

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Plant Simulation, Value stream mapping, Lean production

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CREATING PRODUCTION MODEL USING VALUE STREAM MAPPING TECHNIQUE IN SOFTWARE TECNOMATIX PLANT SIMULATION

Abstract
The paper deals with the creation of a value stream map for the selected manufacturing process in the area of software Tecnomatix Plant Simulation. Because the software has technique Value Stream Mapping, it allows to create a digital value-flow model and gives a more efficient, faster and more dynamic process of processing multiple-product process maps. The advantage is to run the simulation on the created model and to monitor the behavior and then evaluate the simulation outputs. Value stream mapping in Tecnomatix Plant Simulation also has a variety of imaging techniques that are helpful in process of analyzing the value stream being tracked.

1. INTRODUCTION

The key words of today are words such as high productivity, low cost, lean manufacturing, smooth flow, zero bugs, wasted elimination, high speed, low inventory, and the like. To fulfill these words, most businesses need to make some changes. However, the pursuit of any changes is and will continue to meet with some resistance, because no one can say with certainty that the changes will be painless and with clear results. To make changes to increasing productivity, you need to go through these stages [1-5]:

- be aware that change is needed,
- gain knowledge about what needs to be changed and how the change is created,
- want to make this change,
- make change.

In addition to supporting management and business owners, you need to provide tools and features for individuals or teams to successfully implement change. Industrial engineering

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provides precisely these tools and functions, and therefore industrial engineering is considered a catalyst to guide and accelerate change. [6-7]

2. CREATING PRODUCTION MODEL USING VSM LIBRARY IN TX PLANT SIMULATION

Value Stream Mapping (VSM) is a method known in the world for more than 50 years, when it appeared in the Japanese automaker Toyota under the name "Material and Information Flow Mapping". This method of industrial engineering maps the value flow in all processes from material input to production to the actual shipment of material to the customer. The aim is not only to monitor the material flow, but also the information flow in representative labeling of individual processes according to the standard procedures. The very goal of mapping the value flow is not just a map of the current state, but it is also necessary to create a map of the future value flow. Optimizing the value flow is needed for a successful understanding of possible improvements and their benefits for the future value flow. [7-12] One of the most flexible way to create and analyse value flow is modeling and simulation used appropriate software module. Tecnomatix Plant Simulation is a discrete event simulation tool that helps create digital models of logistics systems such as manufacturing to explore system characteristics and optimize performance. Value Stream Mapping Library is an optional accessory in module Tecnomatix Plant Simulation.

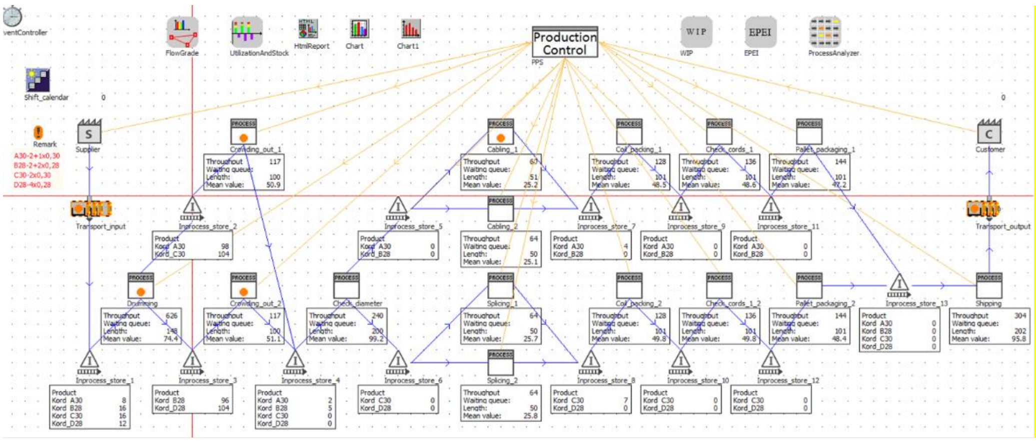

Fig. 1 Current status VSM model of production

The observed production (Fig. 1) can be described as a serial type of production that uses a pull system, acord the customer orders. The current status map describes the individual processes, their status by the production and provides information about each other process in the value flow. The current status map was made based on information provided by employees and by own measurement directly in production. The other information was documents and information about the supplier, the methods of delivery and exact dates, as well as orders, the methods of production management and planning, or the form of finished products. Analyzed the current state of production involves shortcomings and it is therefore necessary to propose adequate solutions to these bottlenecks of production on the grounds that there is waste in the production process, which does not bring value to customers. In order to achieve optimal future state, it was designed and implemented Kanban system in the environment of Tecnomatix Plant Simulation.

3. PROPOSAL OF FUTURE STATE VARIANT USING VSM LIBRARY IN TECNOMATIX PLANT SIMULATION

Overall planning and layout of future state was necessary to cleverly set up and connect all the processes so as to show a situation that could actually happen in the future that these processes have sufficient explanatory power. It is important that the simulation is truly useful to society and sufficiently evident for subsequent application. Future status VSM model of production in modul TX Plant Simulation is shown in Fig. 2.

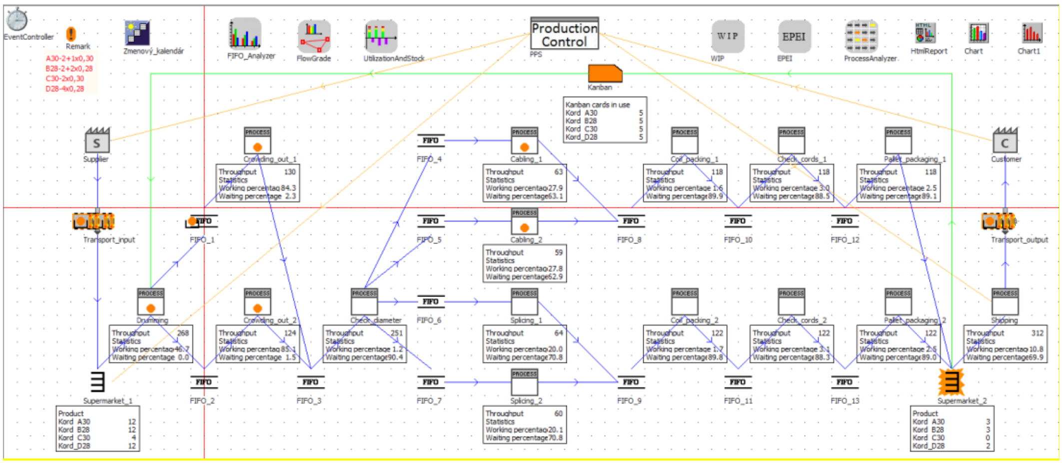

Fig. 2 Future status VSM model of production

If Kanban system is implemented, production stations are more connected because the Kanban system works on the principle of sending a Kanban signal from the last workplace and always transmits a signal that the workstation can receive the stock. Through Kanban's cards, the feedback between production and management is also improved, as the cards will be sold by management and staff. This will also improve information flow and communication at workplaces. The introduction of Kanban would reduce stock levels and eliminate downtime.

4. CONCLUSION

The successful implementation of the changes is based on the synergy of all company employees. Therefore, it is important that workers in engineering and technical-economic professions understand the basic methods of industrial engineering and understand this knowledge as part of their qualifications and a means of improving their current status. By using industrial engineering methods, workers in their workplaces can discover, for example, excessive waste. The use of industrial engineering results in a better working environment and worker satisfaction. Continued productivity improvement is a long-distance run accompanied by hard work, with most workers contributing. The performance of a business and its processes is measured by the ability to respond in different areas. Once a person begins to understand how a process works, he can detect waste and other abnormalities and is able to design a solution.

This article was created by implementation of the grant project VEGA 1/0708 and APVV-17-0258.

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Digital Twin, Factory Twin, Design of Manufacturing Systems

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IMPLEMENTATION OF THE DIGITAL TWIN CONCEPT IN DESIGNING OF MANUFACTURING SYSTEMS

Abstract
The article deals with the design of manufacturing systems using the concept of a digital twin. At the beginning of the article is a brief description of the digital twin. The core of the work is the process of implementing the creation of a Factory Twin, consisting of six basic steps and the interconnection of three worlds, digital, real and virtual. It is the virtual world that distinguishes the classic design of manufacturing systems in a digital factory.

1. INTRODUCTION

Design of manufacturing systems is a term that has undergone a great deal of customization. In the past, 3D objects were used to design manufacturing systems, but they were not in the digital interface but in the real world. Later, production systems in the digital factory began to be designed, where 3D objects were converted into the software. In the 1990s, began to be talked about a digital twin. With the gradual development of information and intelligent systems, the development of sensors that have been able to collect real data from the production process and the pressures of Industry 4.0, the concept of a digital twin can be realized. After applying the digital twin to the produced product, there was a shift in this method, and later the digital twin was expanded to create a Factory Twin.

2. DIGITAL TWIN

The digital twin is a functional system that optimizes processes. It consists of physical production in conjunction with its own digital copy. The digital twin creates an environment in which we

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can optimize traffic directly during the production chain itself, change production parameters and processes, and adapt the product to market requirements. A digital twin is a virtual representation that corresponds to the physical attributes of a factory, system, product or component in real time using sensors, cameras, intelligent systems and other data collection techniques. As a result, we can shorten and streamline the production cycle, shorten the start-up time of new products, and uncover inefficient manufacturing processes [1].

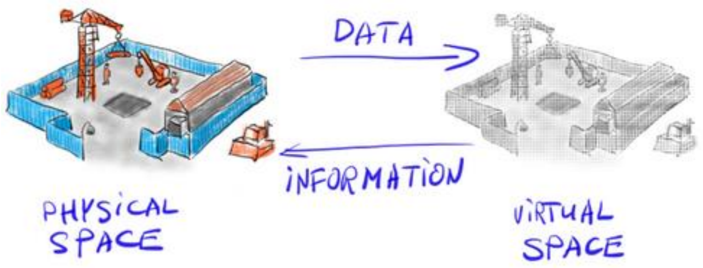

Fig. 1 – Digital Twin

2.1 Design of manufacturing systems using the concept of digital twin

CEIT Smart Factory is an extension of the digital factory by extending this concept to a virtual factory, creating what is called a factory twin in a virtual environment. The realization of Factory Twin can be divided into six basic steps and three worlds, which are described in Figure 2. The concept of digital twin in designing manufacturing systems is a digital world, a real world, and a virtual world. The digital world includes digitization and planning, dynamic simulation and virtual employee training, which is the first part of applying this method. The second part of the application of the design of production systems using the concept of digital twin forms a real factory, where we implement the design in the digital environment and its self-optimization in real time.

Fig. 2 – Factory Twin

The final step of the implementation is to link the virtual model of production system with a real production system, which is actually a Factory Twin [2]. This means that this whole solution integrates three worlds, a real physical factory world, a digital world that is represented by digital models whose dynamics can be analysed using computer simulation and a virtual world that is represented by data that can be optimized using emulation [3].

2.1.1 Digital world

The process itself starts with digitization and planning in a 3D digital factory environment. When designing production and logistics systems, we need to consider technological, construction and financial-economic constraints. In the design itself, we must deal with the analysis of the material flow in the production layout, the design of the warehouse system, the production management system, the handling system, the assembly system, and the project documentation. In order to select the most suitable option for the design of production systems, the length of the material flow, the loading of transport aisles, the minimization of free space in the production layout and the intensity and distance of the material are analysed. After processing these basic steps for designing of production and logistics functions, we move on to the simulation of the proposed solution. After analysing the resulting solution in terms of designing products and logistics functions, the results are verified in terms of dynamic simulation. The input parameters determined at the beginning of the solution are determined and simulation is launched that can perform a number of different experiments in the simulation model. Specifically, it is the utilization of input, intermediate and output warehouses, the total production capacity of production facilities, whether it is the number of manufactured pieces, the production in progress, downtime, failures and so on. Using these indicators, we are able to evaluate data and optimize it before it is introduced in the real world. Before the real implementation of the proposed solution in the real world begins, virtual employee training can take place. With the help of augmented and virtual reality, the employees of the future enterprise can try to work in virtual 3D environment the Factory Twin.

2.1.2 Real world

After applying the first three points that make up the digital environment of the proposed concept, the actual implementation of the proposed solution in the real world can occur. There is an implementation of the proposed solution in the enterprise environment, whether it is the deployment of complex automated logistics systems and implementation of the proposed production lines. The entire operation of these solutions is autonomous, and therefore they can optimize themselves in real time, communicate with the enterprise management system and respond to changes in production requirements in real time. If the solution is implemented in a real environment, the next step is to introduce methods for collecting data from the real production process.

2.1.3 Virtual world

With the real-world operation, we can collect real-time data from the production process using various types of sensors, intelligent manufacturing systems, and information technology. By using these collected data from the production process, we can monitor, and analyse the proposed solution to optimize it in a digital environment. This whole concept of data collection from the production process can be divided into the following basic parts:

- data collection from production machines and equipment,
    - MES, various types of sensors (inductive, capacitive, magnetic, optical…) RFID (tracking material in production process),
- data collection from employee and handling equipment,
    - RTLS – Real-Time Location System,
- data collection from stock management,
    - RTLS, RFID.

2.1.4 Factory Twin

After applying the previous steps (e.g.: digitization and planning, dynamic simulation, and the virtual training in the digital world, implementation and self-control in the real world), the final point is the virtual linking of the virtual world to create the required data from the real production process model with a real production system, that is, creating a Factory Twin. After creating a Factory Twin, we get a comprehensive picture of real production in a virtual environment. The required data is constantly collected, stored and processed in simulation software, where we have designed the Factory Twin [4].

3. CONCLUSION

The whole solution of designing production systems using the concept of a digital twin integrates three worlds, a real physical factory world, a digital world that is represented by digital models whose dynamics can be analysed using computer simulation. Virtual world that is represented by data that can be optimized with using computer emulation [5].

This article was created with support of project: KEGA 020ŽU-4/2019

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Optimization, lean production, manufacturing process, production management

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OPTIMIZATION OF THE PRODUCTION PROCESS

Abstract
In the current conditions of industrial companies on the market, to be and also to remain competitive requires continuous improvement. Increasing quality, at the shortest production time and, last but not least, reducing costs, can be included among the primary goals of businesses.In order to meet these requirements, we have focused on optimizing the time structure of the manufacturing process. Nowadays, the optimization of the production process is one of the most common optimization tasks in industrial enterprises.

1. INTRODUCTION

Each day, our customers think about how best to produce at the lowest possible cost. Yield improvement is a major topic that requires continuous attention in order to remain competitive.
Lean production characterizes an effort aimed at limiting waste of resources, time, as means forsociety to get rid of everything that burdens it in its growth (1). Lean production is not an end in itself to reduce costs. In particular, it is to maximize added value for the customer. Slimming is the way to produce more, have lower overhead costs, to use more efficiently our spaces and production resources (2). The goal is to add value by minimizing the waste or loss of material, time, space and people (3).
Process optimization is the discipline of adjusting a process so as to optimize some specified set of parameters without violating some constraint. The most common goals are minimizing cost, maximizing throughput, and/or efficiency. This is one of the major quantitative tools in industrial decision making (4).

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Optimizing production processes solves problems arising in the production directly related to the production process. Whereas, in the company run several manufacturing processes, problems often affect energy, material, technical and personnel equipment of the manufacturing process (5). For a long time the process optimization was considered as the task of quality management, but today it is increasingly grown as a part of a comprehensive and integrated process management in organizations. Process orientation and optimization as the basis of an effective type of farming is now an indispensable part of any modern business management in order to survive in the national and international competitive environment (4).

2. OPTIMIZING THE TIME STRUCTURE OF THE PRODUCTION PROCESS

The movement of the working objects must be such to ensure a smooth production process. The material flow is therefore regulated by time constraints. The certain course of the work objects in a particular spatial structure of the production process over time formsthe time structure of the manufacturing process (6). The time structure of the production process is from the qualitative and quantitative aspect expressed by the continuous time of production and the proportion of its individual components. Continuous production time is a time indicator that reflects the duration of pre-production stages as well as the duration of production itself (7).

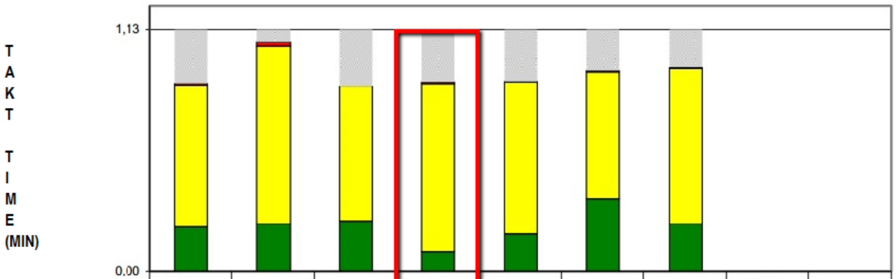
Modern enterprise means not only the use of modern technologies, but also the modern way of thinking of all involved employees. Therefore, with the production systems department in the company, we focused on creating of planning and optimizing the processes of performance creation in its broadest sense, using engineering methods.

Prerequisites for a modern business that is on the path of lean productionfocuses not only on profit but on its employee. This department is present at every optimization, whether it is the use of modern technology to eliminate waste, or in the field of operationally specific qualification of employees.

The optimization of the time structure of the production process took place in one of the industrial enterprises in Slovakia. This company creates time analysis in Workingplan, using the MTM-UAS method, which is a tool to create worker time. The workload of employees is divided at the time of the cycle, which is in our company 68 seconds for:

- value-creating time that gives the product added value and our goal is to maximize
- hidden wastage does not bring value, but it is necessary to carry out value-creating activities in order to minimize it.
- direct wastage does not bring value and is not necessary to carry out value-creating activities, so we try to eliminate this waste.

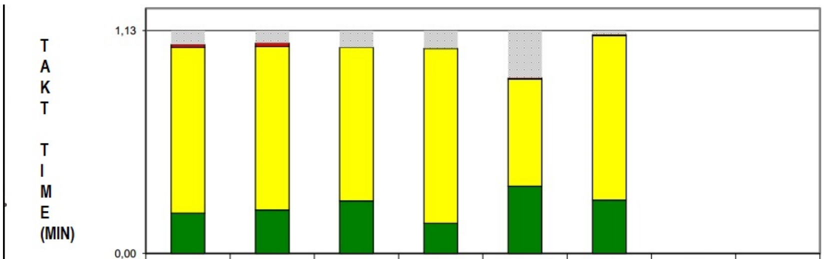
Figure 1 shows the current workload ofworkers in team X, whose total workload is 81.94%. Labor productivity is the most important source of competitiveness. The area of optimizing human resource productivity is constantly trying for improvement by elimination or reducing unnecessary and unproductive activities. That is why after a long-term observation of team X in the company we have decided to redistribute the work ofan employee D. This will ensure not only an increase in labor productivity, but also fulfilment of the workload capacity of the remaining employees and an increase in the overall workload of the team X.



	A	B	C	D	E	F	G	TEAMLEADER	Σ Kredit
disposition time	0,2505	0,0596	0,2645	0,2441	0,242	0,1938	0,1779	0	1,4324
	0	0	0	0	0	0	0	0	0
direct waste	0,0075	0,0177	0	0,0075	0,0008	0,006	0,006	0	0,0455
	0	0	0	0	0	0	0	0	0
hidden waste	0,6703	0,8361	0,631	0,7914	0,7165	0,5975	0,7288	0	4,9715
value-creating time	0,205	0,22	0,2379	0,0903	0,174	0,3361	0,2207	0	1,4839
process time	0	0	0	0	0	0	0	0	0
occupancy	77,89%	94,74%	76,66%	78,46%	78,65%	82,90%	84,30%	0,00%	81,94%
workplace	1	1	1	1	1	1	1	0	7

Figure 1: Workload of team X in an industrial company

In Figure 1, we have indicatedan employee D and, at the same time, the total workload of team X which represents 81.94%. When changing the tact of the workplace and removing worker D, see Figure 2, we reached the X-team's workload of 91.61%, which represents a 9.67% increase in team productivity.



	A	B	C	D	E	F	TEAMLEADER	Σ Kredit
disposition time	0,0708	0,0632	0,0856	0,0906	0,2407	0,0196	0	0,5706
	0	0	0	0	0	0	0	0
direct waste	0,015	0,0176	0	0,0007	0,0064	0,0064	0	0,0461
	0	0	0	0	0	0	0	0
hidden waste	0,8425	0,8318	0,7803	0,8887	0,5444	0,8359	0	4,7235
value-creating time	0,205	0,2207	0,2674	0,1534	0,3418	0,2715	0	1,4598
process time	0	0	0	0	0	0	0	0
occupancy	93,75%	94,43%	92,45%	92,00%	78,76%	98,27%	0,00%	91,61%
workplace	1	1	1	1	1	1	0	6

Figure 2.: Workload of team X after removing employee D

By removing employee Dwe will achieve the primary goal – increased labor productivity, improved performance, but also reduced costs. All changes were made in terms of technological sequence together with the planning department, where they paid attention to the correct redistribution of operations not only according to the technological procedure, but also on the basis of time sequence. Although the goal of industrial enterprises is 100% workload, our proposal has brought us closer to the above-average utilization rate and thus to the improvement of the use of human resources.

3. CONCLUSION

By increasing the productivity of the production area, we will meet the core idea of productivity for the society, making the right things right for the first time and every time so that competitiveness is the most important resource. Businesses should not seek behind increase in productivity the costs to increase automatization, but rather focus on reserves in the current structure and optimization of production processes themselves.

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Industrial Engineering, Manufacturing Design, Software Solutions

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CEIT TABLE, SYSTEM FOR INTERACTIVE EVALUATION AND DESIGN OF PRODUCTION DISPOSITION

Abstract
Businesses are primarily focused on improving the efficiency of internal processes. Therefore, production plants need a realistic picture of their current status. All this will only be possible through the implementation of new technologies and the transformation of existing factories through digitization. This combination must be based on planning that is currently provided by interactive software scheduling systems. The article deals with the use of software solutions for the analysis and planning of production and logistics systems.

1. CURRENT PROBLEMS IN PRODUCTION DISPOSITION

Ensuring continuity and quality of production leads some organizations to think about the current state of logistics and manufacturing systems. Management lacks data, information, methods and tools for decision making. The problem is that planning - production and logistics management is based on the principles that have been used for over a hundred years. Over the past twenty years, the Lean Management and Six Sigma - Factory Principles have progressed successfully. But today it is not enough. The combination of these principles with digitization brings new quality of decision-making data. [1]

1.1. Problems related to the design of production and logistics systems

Nowadays, there are problems related to the design of logistics systems in automobile manufacturing and manufacturing organizations. The main problems are cited [2]:

- Inaccurate scheduling due to inaccurate or incomplete data.

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- Missing or inefficient software, flaws in information flow.
- Human errors resulting from insufficient system of work, lack of rules, motivation.
- Oversized, undersized capacities (workers, handling equipment, areas, warehouses).
- Problematic data acquisition, insufficient validity and outdated data.
- Inefficient packaging, missing packaging regulations, insufficient overview of material flow.

2. SOFTWARE SOLUTION FOR DESIGN SUPPORT

High-level, proven methodologies are complemented with new technologies today. Designing is actually about collecting information, processing it, creating analyzes, finding the best design and verifying it. It is an old methodological approach, but new technological possibilities give it a completely different dimension and added value. [3, 4] The digital copy of the real system is analyzed with a software tool easier than it would have been in the past.
Ceit Table software solution, a tool for designing production and logistics systems in a 3D environment. The system includes features and work modules to help make work and decision making on production layouts and logistics systems. Designing logistics systems in this software is at the very beginning of processing input data. The basic input data needed for the analysis of the logistics and production system can be divided into the following categories, data on:

- Parts: part number and name, part weight, packaging type, number of pieces in package, length, width, packaging height, net packing weight and stack ability.
- Manufacturing processes: manufacturing process with basic information (operation number, operation name, unit production time, workplace / machine on which the operation will be performed.
- Available times of individual categories of production sources (headquarters, worker): number of hours to change, number of available days per year.
- Up-to-date logistics supply schedules, staging points, staffing and handling equipment. [5, 6]

Consequently, an external data file is created from the collected data, which is imported into the software environment (Fig. 1). Such a piece of data source is called BOM (Bill of Material), and in this way it is then possible to directly allocate parts for processing according to the manufacturing process.

	CisloDielu	NazovDielu	HmotnostDielu	TypBalenia	MnozstvoVBaleni	DlzkaBalenia
1	Číslo dielu	Názov dielu	Hmotnosť dielu	Typ balenia	Ks v balení	Dĺžka
2	52701-D7200	Aufnahmebock E3	0.010000	007102	300.000000	1200.000000
3	52701-D7210	Bremsabdeckblech HA links 18" - 20" E3	0.010000	003147	500.000000	297.000000
4	52701-D7010	Bremsabdeckblech HA rechts 18" - 20" E3	0.001000	003147	900.000000	297.000000
5	52701-D7300	Bremsabdeckblech VA links 18" - 20" E3	0.001000	003147	1900.000000	297.000000
6	55100-D3050	Bremsabdeckblech VA rechts 18" - 20" E3	0.001000	003147	1900.000000	297.000000
7	55210-D3050	Bremsleitungen E3	3.520000	111970	60.000000	1600.000000

Fig. 1 BOM (Bill of Material) external data source created

The classic design of manufacturing and logistics systems is much more flexible and efficient thanks to the use of modern digital technologies and procedures. The created production disposition objects embedded in the Ceit Table system are not only about the actual creation in terms of classical modeling in graphic software. The machine model in this system is a parametric object that is composed of multiple contents. These contents allow the objects to communicate with each other and allocate operations and parts to them from the external data source BOM, BOO. Thus, the production system modeling is based on the current state. After parameterization of individual objects, the spatial layout is modeled using the embedded drawing of the production layout (Fig. 2). Based on the previous steps, the software can already provide information about the size of areas, their built-up and unstopped areas when deploying objects, visualizing the service zone of the object, etc.

Fig. 2 Creating a digital copy of the system based on the current state

After designing the production layout, it is necessary to proceed to the planning of the logistic supply. By designing a logistics system, it is possible to verify the proposed production system in terms of logistics. In the software solution, material flow modeling is solved using a tool in the form of a checkerboard of transport relations (from where to). After the creation of the individual material flows and supply circuits, it is possible to allocate these flows and circuits to individual service handling means. To Fig. 3 is a tool for evaluating the handling means used in a logistics system.

Fig. 3 Capacity evaluation of handling and transport means

Evaluation for fig. 3 speaks about the extent to which the individual handling means are used on the basis on the current logistics supply plan.

Tab. 1 Material Handling Capacity (Current System Status)

Truck Name	Total distance traveled [m]	Total Capacity Extraction [%]
AGV_01	26 480,62	98,08
AGV_02	34 003,95	125,94
VZV_01	15 839,95	58,67
VZV_02	22 276,88	82,51

More specifically, the problem of capacitive loading of handling means is shown in Tab. 1. The results of the analysis also confirmed the mentioned problems of logistics systems in the companies such as:

- Insufficient overview of material flow.
- Problematic data acquisition, insufficient validity and outdated data.
- Missing or inefficient software, flaws in information flow.
- Inaccurate scheduling due to inaccurate or incomplete data.
- Oversized or undersized capacities - people, transportation technology.

The tool includes features and work modules to help you work and make decisions when designing a new logistics system and logistics supply plans. After entering the input parameters, it is possible to evaluate them interactively by means of the tool, considering the state and nature of the production disposition.

3. CONCLUSION

New functionalities of software solutions are already necessary in designing and evaluating the design of complex manufacturing and logistics structures. Software solutions that stimulate mutual communication and interaction of individual system objects offer an effective design creation tool that can be changed without the hassle of changing each system element. This means that changing the system element recalculates individual parameters and relationships between other system objects. The system reacts flexibly to changes and with its help it is possible to determine how the changes will affect the system in a wider understanding. Thus, the support design tool with interconnected and communicating elements can convey information and feedback in the process of creating change for further decision-making by industrial organizations.

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-16-0488

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Logistic System, Software Solution, Design

Michala ŠELIGOVÁ*, Eva SLAMKOVÁ**, Ivana ČECHOVÁ***

DESIGN OF LOGISTIC SYSTEMS

Abstract
Designing in recent years has undergone rapid development. The design principles are more or less the same, but modern high-tech technologies that contribute to better design are used for design. The advantage of these modern technologies is their wide use, which mainly brings quality and precision into the design. Technologies and concepts such as virtual reality, augmented reality, digital factory, reverse engineering, and simulation of manufacturing and logistics systems bring the solution to the problems of designing production and logistics systems into a virtual environment.

1. LOGISTICS SYSTEM

We use the logistics system (Fig. 1) as a tool for systematic description of objects with a focus on exploring existing or designing the intended logistical activities associated with circulatory processes. That is, all activities related to material and information flows.[1]

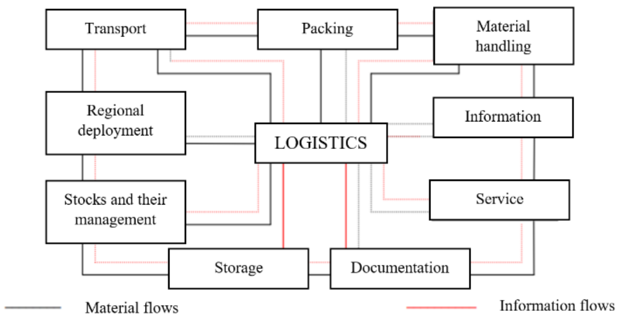

Fig.1. Subsystems of logistics system [2]

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These are mainly activities related to the transformation about customer needs into a logistic goal – requirements – for so-called logistic product. This includes activities related to the transformation of a tangible (or intangible) product that meets the customer's needs in accordance with this objective. [1]
The logistics system consists of several components, ie subsystems. Each component is dedicated to performing physical and information flows, and each subsystem is related to others. Changes from any of the components have a greater or lesser effect on the other components. [2]

1.1. Current software solutions for designing logistics systems

Currently, highly sophisticated solutions are available on the market that provides a wide range of functionalities, whether they are logistics resources themselves, equipment used by logistics personnel, monitoring, and control information systems. On the one hand, these solutions are a great opportunity to improve in-house logistics. On the other hand, they are usually associated with high financial investments. Designing a new logistics system, respectively a significant change in the existing logistics concept, it is a challenging optimization task. Therefore it is necessary to devote adequate attention to it and use adequate tools for the solutions.

1.1.1 CEIT Table

CEIT Table represents an interactive tool for supporting intuitive, team-oriented design of logistics systems. It works on a variant of a hardware platform designed for interactive design of production and logistics systems in a 3D environment on a large multi-touch display surface.

This interactive design system is designed both as a tool for designers and as a tool for designing new or redesign old logistics systems. Project team members can work together to design a new production layout through 3D models, interactively change layout based on monitored parameters, and verify/select the best option through simulation.

Funkcitionality of CEIT Table:

- visualization of material flows,
- optimization of material flows,
- material flow modelling/planning,
- modelling of logistics networks,
- 2D/3D visualization,
- manufacturing systems modelling/planning,
- interactive evaluation of the solution.

1.1.2 Tecnomatix software

Siemens delivers its own digital business solution concept that connects design, ergonomics, and simulation programs to increase design efficiency and change verification. Tecnomatix is an open technology PLM (Product Lifecycle Management) system that provides clear information about manufacturing decisions, analysis and results through powerful productivity tools and a more intuitive user interface. It plans, optimizes and validates manufacturing processes before production begins. With advanced planning, simulation, and information exchange tools, greater efficiency and productivity can be achieved by synchronizing product and process development phases. [3]
Tecnomatix tools include FactoryCAD and FactoryFLOW, which are extremely powerful tools to support digital manufacturing systems design. FactoryCAD is an extension and library of

parametric models for AutoCAD software. Thanks to its parametric 3D models, it enables fast production layouts. The data is used as input to the FactoryFLOW module designed to optimize material flows and to arrange manufacturing disposition using a variety of known methods. Tecnomatix FactoryFLOW is a software module for the analysis and optimization of material flows and material handling, which allows to optimize the spatial arrangement of production based on transport distances, frequency and cost. It uses transport route analyzes, material storage requirements, material handling equipment specifications and component handling unit information for a given production system arrangement..

1.1.3 Plant Simulation

Another tool from the Tecnomatix range is Plant Simulation, which enables you to quickly create realistic simulation models for dynamic warehouse and logistics operations. Plant Simulation enables to evaluate design features and performance of design alternatives long before they are implemented in real processes. It allowing to make smarter decisions and minimize design rework.

Plant Simulation, as a comprehensive tool for simulating production and logistics systems, contains a large number of specialized modules. For example, the simulation areas developed by Plant Simulation include:

- simulation of production and assembly processes,
- simulation of logistics activities,
- simulation of human resources,
- 3D computer simulation,
- use of optimization using genetic algorithms and others.

1.1.4 VisTABLE

VisTable is a support application for the static design of manufacturing systems. The software is characterized by its simple operation. It includes applications that make it easier for the designer to work and make decisions when designing the layout of workplaces and the entire production layout, but also when designing other spaces such as office, public, etc. The environment of program VisTABLE contains tools to support basic activities related to production layout design:

- interactive layout design in the project team,
- material flow analysis,
- flexible adaptation of production to commercial and innovative changes,
- team-refined, detailed space structure designs,
- checking and maintaining minimum distances,
- evaluate of layout design.

1.1.5 MALAGA

MALAGA is a comprehensive software package for logistics planning and production planning. The architecture of this logistics and production planning software is simple and standardized, making software operation extremely easy. Planning results are known for their ability to significantly increase productivity during all planning levels. In addition, the program modules have additional characteristics that enable planning and management synergy. With the "Massimo V3" simulation interface, all planning data from Malaga can be utilized, including the production plant to create the Plant Simulation. No expert knowledge required – the simulation runs completely in the background, so no interaction with the user is needed.

Basic system features:

- calculation of cost and depreciation,
- capacity calculations,
- utilization of traffic routes,
- analysis of running times,
- display material flows in the layout,
- view stores in the layout,
- display area and route usage in layout,
- automatic determination of cost-optimal logistics routes,
- suggesting round routes,
- export results to PowerPoint.

2. CONCLUSION

The speed, reliability and efficiency of enterprise logistics processes can significantly impact the performance and productivity of the entire enterprise. Perfect management of business logistics provides a strong competitive advantage to the company's management. Currently, highly sophisticated solutions are available on the market that provide a wide range of functionalities, whether they are logistics resources themselves, equipment used by logistics personnel, monitoring and control information systems. On the one hand, these solutions are a great opportunity to improve in-house logistics. On the other hand, they are usually associated with high financial investments. Designing a new logistics system, resp. A significant change in the existing logistics concept, it is a challenging optimization task and therefore it is necessary to devote adequate attention to it and use adequate tools for the solutions.

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-16-0488

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Assembly process, Process Designer, Process Simulate

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PROCESS DESIGNER AS A TOOL FOR ASSEMBLY LINE DESIGN

Abstract
This article deals with the design of the assembly line using the Siemens Tecnomatix software module. Process Designer is a widely used module, through which it is not only possible to statically design a workplace layout, but also to analyze future production using the simulation of individual manufacturing activities. Outputs from the mentioned software will help us to identify deficiencies and to eliminate them.

1. DESCRIPTION OF ANALYZED ASSEMBLY LINE

The assembled assembly line completes the double-clutch automatic transmission. The analyzed workplace consists of two assembly lines, which represent one of the most important workplaces of the company. The final assembly of the gearbox takes place on these two assembly lines, ie the assembly of the individual parts from the gearbox itself, through the gears, shafts, to the closing of the gearbox and transfer to another workplace. The following diagram (Fig. 1) shows the basic layout of MPS I and MPS II assembly lines.

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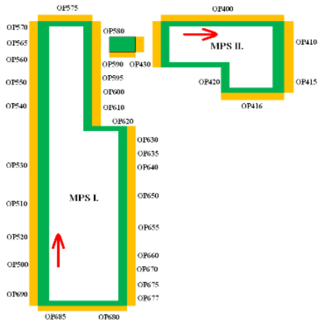

Fig.1. Basic layout of MPS line workplaces

2. LINE OPTIMIZATION

Based on the analysis of the selected MPS assembly line and the individual outputs using Tecnomatix Process Designer software, there were little shortcomings in the use of resources during assembly. Specifically, it is an assembly line MPS I. and workplaces OP540 and OP610 (Fig. 2).

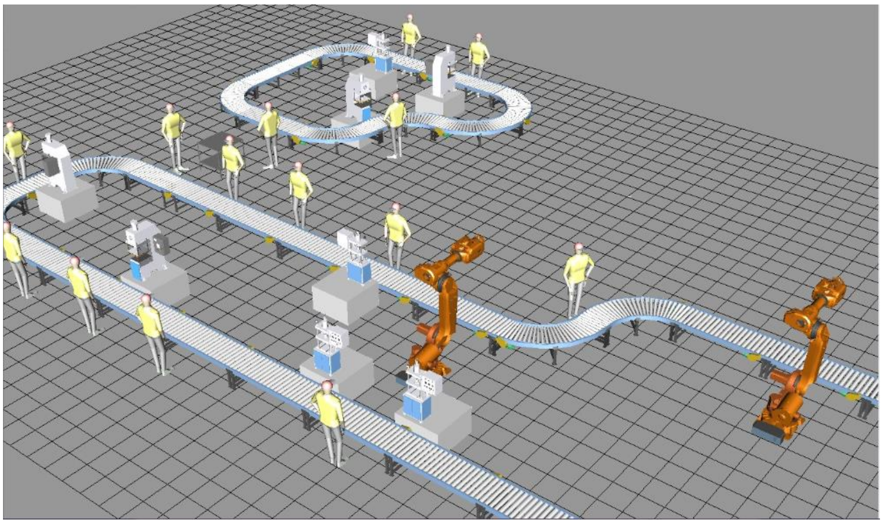

Fig.2 Workplaces OP540 and OP610

2.1. Original state of OP540 and OP610 optimized workplaces

In addition to stamping, the OP540 also performs the lubrication of the gearbox component. This activity is performed by one worker on the line. After the lubrication is completed, the operator moves along with the gearbox to OP550, where he presses the bearings. Compared to the OP540 workstation, robot sealing is applied to OP610. The total operation time of OP540 is 41 seconds, where the transmission waiting time is 2 seconds, the component is pressed for 24 seconds, and the above-mentioned lubrication is 15 seconds. The following diagram (Fig. 3) shows a detailed view of the optimized workstations in the original layout.

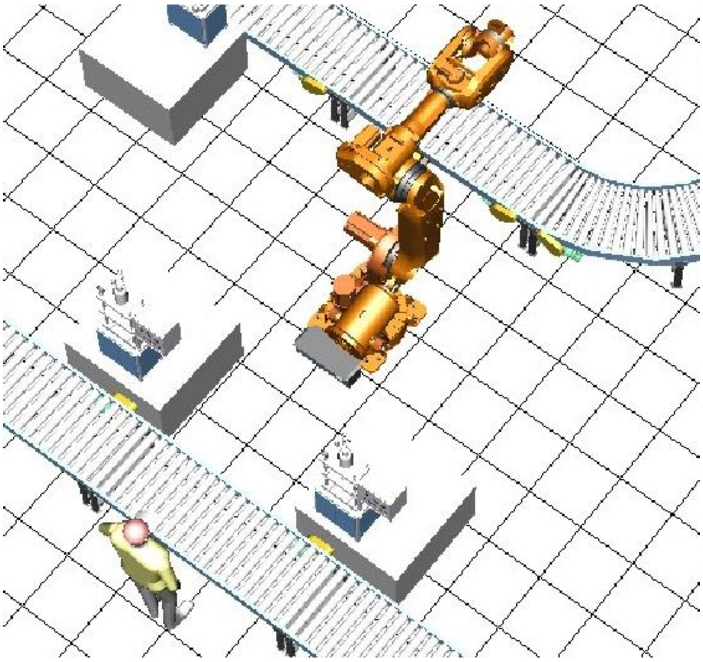

Fig.3 Detailed view of OP540 and OP610 workplaces

2.2. Proposed optimization of OP540 and OP610 workplaces

The operation of lubrication of the gearbox component can be replaced by suitable synchronization with the workplace OP610. This operation of applying the seal to the gearbox is carried out by the KUKA robot with a time of 60 seconds. The previous operation is OP600, which lasts 93 seconds. As a result, OP610 is a bottleneck. This downtime can be utilized by component lubrication activity. The OP610 robot has a 33 second time reserve. The total robot time required to lubricate the transmission component is 7 seconds, which saves 8 seconds from previous worker lubrication time (15 seconds). The assembly line has a production cycle of 120 seconds. This means that every single piece of assembled gearbox leaves the conveyor belt every 120 seconds. The total saving of 8 seconds increases the production cycle to 112 seconds. The assembly line works in a 3 - shift operation where one change takes 8 hours. Thus, 720 pieces of gearboxes per working day were produced prior to optimization. After optimizing the installation time, the line is capable of producing 771 units, an increase of 51 gearboxes. The percentage increase in production is about 7%, which is not a negligible number. Thus, human activity will be replaced by a robot that is faster, more accurate, and its efficiency utilization will be greater than in the original arrangement. However, with this proposal, it is necessary to eliminate possible collisions and new downtime of other workplaces. This stems from the tact of production and thus the continuous continuity of individual operations may be disrupted by the proposed changes. Using the Display Longest Path function, a change in the total time required to produce one gearbox was found. It was shortened from the original 1810.5 to the resulting 1802.5 seconds.

The advantage of this optimization is to minimize the cost of change. There is no change in the layout of the workplace as OP540 is in close proximity to the robot on OP610. However, it is necessary to reprogram the robot that will perform the extra activity while ensuring the safety of the robot by exposing the appropriate barriers and safety sensors. Since the company could not provide the individual prices of these items and some of the works can be procured on its own, it was not possible to quantify the total price for the proposed optimization.

ACKNOWLEDGEMENTS

This article was created by implementation of the grant projects VEGA 1/0708/16 "Development of a new research methods for simulation, assessment, evaluation and quantification of advanced methods of production", KEGA 030TUKE-4/2017 Implementation of innovative instruments for increasing the quality of higher education in the 5.2.52 Industrial engineering field of study and APVV-17-0258 Digital engineering elements application in innovation and optimization of production flows.

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Operation research, queuing model, simulation of G/M/c/K, Witness

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SIMULATION OF G/M/C/K QUEUEING MODEL FOR PLANNING OF E-CARS CHARGING UNITS

Abstract
The article is providing a process depiction for a search of a proper queuing model with the assistance of Witness simulation program. The behavioral pattern of system depends on the time span of arrival process, service time and number of servers and places in the system. These criteria are defined in the beginning. The simulation consists of verification and validation steps and optimal solution search through the form of change in number of servers and places in the system in order to find the minimal cost function while meeting the limiting conditions.

1. MOTIVATION

The developing electro-mobility requires the effective and functional realization of vehicle charging during which the charging processes and costs are equally balanced. The balance can be assumed if the found number of places in the system, for which the maintenance costs are minimal and the time spent in the system to meet the requirements is acceptable. From the perspective of relatively long charging periods, it is convenient to implement charging units to parking lots by the malls. To the possibility of getting closer to the behavior of the real system, two different time periods of charging are simulated, i.e. two different types of charging units/ plugs (marked as A and B) as a queuing system (QS) with a changing number of the incoming cars. This implies a varying capacity utilization of the units during a day, week or weekend. The system functionality conditions are: charging of all the cars, the time spent in the queue cannot exceed the waiting time of two hours and the average working time of the unit cannot drop below eight hours a day. The trial phase of the system is assumed to spot breakdowns of the units.

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2. DESCRIPTION OF WANTED QUEUING SYSTEM

To solve a task, it is needed to properly choose data, which are consequently processed. The queueing system is a stochastic system, i.e. the characteristics are random variables. Their behavioral pattern may be roughly described by probability distributions. Then, their process describes the behavior of the real system. The model report corresponds with Kendall's notation according to [1].

2.1. The arrival process distribution $G\ (E(X), \alpha, \beta)$; $Exp\ (\lambda)$

The arrival rate of incoming cars varies depending on certain parts of a day. The same differing principle may also be probable for the weekend arrival rate λ_1 and the week arrival rate λ_2. A sufficiently big selection corresponds to the behavior of arrival rate to continuous distribution. The distribution, or the normality of distribution is tested via the Chi-squared test. Should the normality test verify the distribution, the nearing value of the tested criteria to the χ^2 kvantil value grows the skew probability or sharpness of distribution. Therefore, the tested form is divided into skew $\alpha(X)$ and sharpness $\beta(X)$. Distributions of arrival rates are: during weekend A: $G\ (5{,}0;\ 1{,}7;\ 1{,}7)$, B: $G\ (4{,}8;\ 0{,}4;\ -0{,}7)$; during week A: $Exp\ (6{,}7)$, B: $G\ (9{,}6;\ 0{,}4;\ -1{,}4)$.

2.2. The service time distribution $Exp\ (\mu)$

Should the μ be service rate, i.e. the average number of cars charged in a time unit, the probability description of charging time of one car is an exponential division with the expected value 1/μ. Should a car be charged, the customer is warned via a mobile phone message and has to repark the vehicle, therefore the same amount of time required to charge a vehicle is to be expected. Should the electric car arrive without an available charging unit, it waits for a charging unit at the waiting parking lot until a charging unit is available (message to an owner a preceding car has been fully charged). To describe the service length of each requirement, the exponential distribution with the expected value of 40 min (μ=1,5) for A units and 30 min (μ=2) for B units.

2.3. The failure rate and downtime of charging units - $LogN\ (E(X), \sigma)$; $Tri\ (a, b, c)$

The breakdown rate of the units is requested as per normal logarithmic division with the expected value parameters of 3 days and standard deviation of 0,2. Downtime is set as triangle distribution. The quantity of blackouts at the beginning of the service launch is larger compared to the later service. In case of an unexpected blackout of a unit, a service worker is supposed to be available in a time span between 15 minutes to 2 hours.

2.4. Requirement of model stability

Preventing the cumulation of requests in the queueing system, i.e. a queue does not cumulate on a linear day to day basis, the server utilization ρ must meet condition of:

$$\rho = \frac{\lambda}{c_{min}\mu} < 1 \quad => \quad c_{min} > \frac{\lambda}{\mu} \tag{1}$$

c_{min} is a minimal number of parallel charging units in the system. This means that for A units: $c_{min} > 8$ ($c_{min} = 9$) B: and for B units $c_{min} > 6$ ($c_{min} = 7$).

2.5 Mathematical formulation of problem
The purpose of simulation is to find such a system of mass service where number of servers and x_k is buffer size, i.e. the number of places in the system, $x = x_c + x_k$, for which the overall expenses of the service traffic are minimal and at the same time the conditions of average unit utilization are met and the maximal buffer time T_{fmax} is not exceeded.

Linear function to be minimized:	$N(x_c, x_k) = N_c x_c + N_k x_k$	(2)
With problem constrains:	$1 > \frac{\lambda}{x_c \mu} \geq 0{,}33 \frac{\lambda}{x_c \mu}$	(3)
	$0\ h \leq T_{fmax} \leq 2\ h$	(4)
	$x_c \geq c_{min};\ x_c \in N^+$	(5)
	$x_c + x_k \leq x;\ \ x, x_k \in Z^+$	(6)
	$N_c, N_k > 0,\ N_c > \ N_k$	(7)

The minimal values of variables x_c and x_k are searched. Their weights are units N_c, N_k. The searching final solution is simulated as follows:

$$min\{N(x)\} = N_c * min\{x_c\} + N_k * min\{x_k\} \tag{8}$$

3. SIMULATION OF QUEUING SYSTEMS

As a result of difference in behavior of arrival process during weekends and during weeks for A (G/M/9/217/∞/FIFO) and B (G/M/7/217/∞/FIFO) units. Verification of model accuracy, evaluation of the system view from the perspective of structure and behavior or just partial verification of functionality are subjected to the model verification. [2], [3]. In the case of QS, it means to verify the meeting of system stability conditions. The procedure is carried out via weekend models because the number of charging units for the weekend and the week model is the same and the number of car entries into the system is higher during the weekends. Should the condition of increasing queues for the weekend model be met, so will be also met the condition of not increasing queues during the week. Simulations for 1 day without a breakdown of the system and for 10 days with system breakdowns is set. The 10 days simulation is convenient because each event occurs minimally 10 times. [2]. The model validity is carried out after a successful verification process. That is the evaluation of the model behavior, believability, model quality, agreement with the system behavior. [2], [3] In the case of final model validity verification, the simulation is carried out for models during the week for the same time periods of simulation as well as for verification. The simulation confirms the model validity but a condition of maximal buffer time is not met which does not provide a solution to a problem. Different solutions are searched for via experimentation.

4. EXPERIMENTATION

The experiments are being realized in steps for which different values of variables are set. The limit for variables in experiments are based on the validity evaluation, see Chart 2.

Chart 2 Setting of variables

Condition	Unit A	Unit B
$\boldsymbol{c_{min} \leq x_c \leq \frac{\lambda}{0,33\mu}}$	$\boldsymbol{9 \leq x_c \leq 24}$	$\boldsymbol{7 \leq x_c \leq 18}$
Setting $\boldsymbol{x_c}$	$\boldsymbol{10 \rightarrow 24}$	$\boldsymbol{8 \rightarrow 18}$
$\boldsymbol{x \geq x_c + x_k}$	$\boldsymbol{46 \geq x_k \geq 0}$	$\boldsymbol{50 \geq x_k \geq 0}$
Setting $\boldsymbol{x_k}$	$\boldsymbol{46 \rightarrow 0}$	$\boldsymbol{50 \rightarrow 0}$

A domain of the variable x_c is searched from below. A domain of the variable x_k is searched from above which prevents the premature exit of the car from the system. Service utilization, maximal buffer time and the exit value of x_k are observed in the simulation while the simulation time is 10 days. Already in the first set, the B units model violates both conditions. For model A units, variables are set in two stages. In both settings, only one condition is violated.

5. SUMMARY OF RESULTS AND CONCLUSION

According to the results of the experiment, there is not an acceptable solution while meeting all the conditions of purpose-built functions for certain models. The found models are close to the acceptable models of the system and results dependent on distributions of random variables. The minimal cost functions are in Chart 3.

Chart 3 results of simulation

	Variation of $\boldsymbol{N_c > N_k}$	Minimal cost function
Chargind units B		$\boldsymbol{N(x) = 8N_c + 39N_k}$
Chargind units A	$\boldsymbol{0 < N_c < 10N_k}$	$\boldsymbol{N(x) = 11N_c + 25N_k}$
	$\boldsymbol{N_c > 10N_k > 0}$	$\boldsymbol{N(x) = 10N_c + 35N_k}$
	$\boldsymbol{N_c = 10N_k \neq 0}$	$\boldsymbol{N(x) = 10N_c + 35N_k = 11N_c + 25N_k}$

The found minimal cost functions are independent on the type of costs. This is applicable to both service unit costs and unit acquisition costs. Thanks to variation of unit costs, the choice of a proper model based on the location of system implementation is assured.

This publication was written at Technical University of Liberec as part of the project (21278) – “Optimization of manufacturing systems, 3D technologies and automation” with the support of the Specific University Research Grant, as provided by the Ministry of Education, Youth and Sports of the Czech Republic in the year 2018.

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Reconfigurability, Adaptability, Reconfigurable Manufacturing Lines

Vladimír VAVRÍK* , Milan GREGOR*** , Patrik GRZNÁR***

THE SUGGESTION OF METHODOLOGY FOR DESIGNING MANUFACTURING LINES VIA CHARACTERISTICS OF RECONFIGURABILITY

Abstract

The article provides the solution of problems current manufacturing lines via core characteristics of reconfigurability and their application to particular problems of designing and optimization of manufacturing configuration. Based on these characteristics was created a methodology for the design of the reconfigurable manufacturing line configuration. The conclusion contains the suggestions for the further widening of this new paradigm for design manufacturing lines.

1. INTRODUCTION

Production and assembly lines are currently widely used to produce a wide range of usually more complex products. However, the increasing complexity of the products is a major consequence of problems in the design and operation of the manufacturing lines. It can also be said that the increase in the number of components and their possible variations in the product also significantly affects the overall structure of the production system. As a result of these changes, it is necessary to take into account a number of factors and criteria in the design process itself so that the optimal result is achieved. The current proposal of manufacturing lines has a comprehensive structure and it is difficult problems for many enterprises [1]. For the design of production lines is needed to consider many options and objectives for optimal result. Many studies describe academic methods for optimal solutions, but they don´t solve their feasibility for real conditions in the manufacture. This issue causes several factors as input data, the problem of multiple objectives, variability, layout, and scheduling. The aforementioned problems from the change in the line configuration could be partly removed by the following methodology which takes into account future possible changes in production facilities

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due to the change in the portfolio of manufactured products. This methodology applies individual basic characteristics to create a new approach to designing current systems. The basic characteristics of reconfigurable manufacturing systems used in this methodology are customization, scalability, convertibility, modularity, integrability, and diagnosability [2].

2. THE METHODOLOGY FOR DESIGN PRODUCTION LINES

The concept of the methodology is possible to divide into more parts. Each part this methodology has own function, where only integration these parts can fulfill the purpose for reconfigurable manufacturing line (RMS) design. Considering that, the RMS require to change their configuration in depending on market demand in a short time, is necessary to use principles of reconfigurability in each suggestion part. The parts of methodology (Fig. 1) will be called modules, where each module include own structure. In the next section will be described, individual modules and their main functionality for methodology.

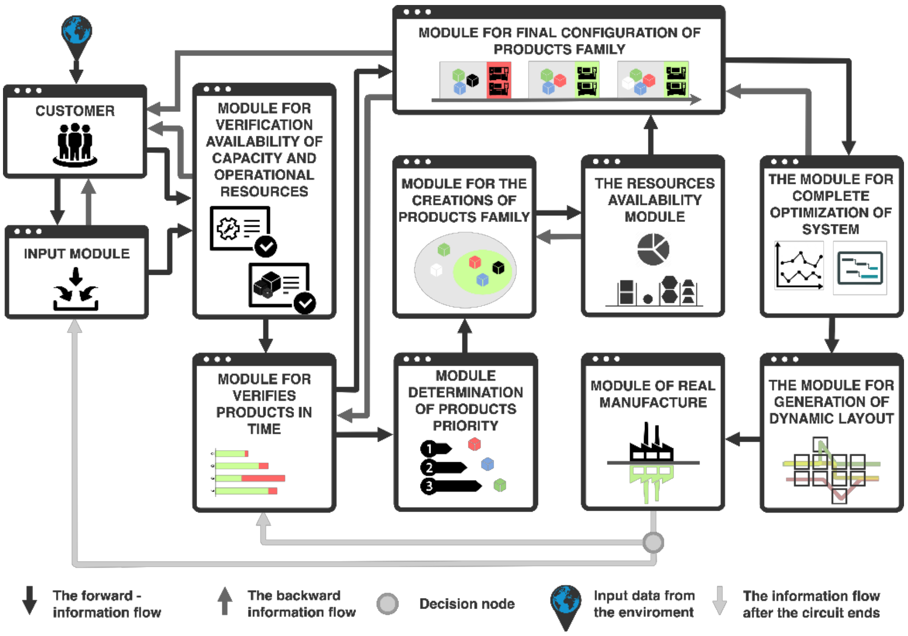

Fig. 1. The block diagram of a methodology for designing manufacturing lines via characteristics of reconfigurability

The first module is termed as CUSTOMER because the customer order is an entry point in a real environment of manufacture. The customer in this meaning is the sales department which in factories secures plan of orders, communication with a customer and buying of materials. In this module is the sales department represented by input data which are generated in a predetermined range. This data is sent on the next module.

The next module is called an INPUT MODULE and his primary function is the storage of input parameters. However, the second function of this module is the actualization of these parameters. These parameters are updating in the case if the new product family was created or changed.

Each change is sent the customer for approval. If the customer agrees with the changes of the parameters, the module adjusts it.

If the order has been assigned, it is necessary to verify his processability. This function ensures the next modules, which are described in the next paragraph. The first examination of processability does in the MODULE FOR VERIFICATION AVAILABILITY OF CAPACITY AND OPERATIONAL RESOURCES. The part for the verification availability of capacity resources compares the count of required machines with the count of machines in the designed system. The initial count of machines in the designed system depends on many factors. For example, the expected size of the factory, the extent of investment for building, prediction for the future selling of products, etc. The second part compares the types of operations assigned for a particular product with the type of operations which can be done in the designed system. When the designed system can produce each type of operation on the assigned product. Then the product is possibly made in the designed system. If the particular product does not fulfill defined requirements of capacity and operational, it is necessary to inform the customer. The customer must change product parameters because the product will not be made. The other ways are to add new functions and increase the capacity of the designed system for an unprocessable product, but only if the product will order in regular.
The product can be made in a very short time if the uses of capacity system resources increase on maximum height. The parameter of a short time then can indicate product processability for the actual defined products. When a family of products does not contain all products defined by customers, the remaining products must be verified via this short time producing parameter. The module which contains this verification rule is named as a MODULE FOR VERIFIES PRODUCTS IN TIME.
The last module for verification defined product is the MODULE DETERMINATION OF PRODUCTS PRIORITY. The function of this module is the analysis of the similarity between products, according to time for manufacturing and the similarity of product operations. The result of this module is a sequence for assigning products to the products family.
The main part of the methodology is a MODULE FOR THE CREATIONS OF PRODUCTS FAMILY, which is comprised of more parts. The firstly part contains methods for clustering products to each other and defining input parameters for the determination count of machines for this group. The function of the second part this module is, therefore, determination of the count of needed machines for created cluster. Then, the count of machines this cluster is tested by simulation. The simulation model is created as parametric, that means, that every new cluster is possible to simulate with his count of machines and other parameters. The count of the machines is suitable if all the production volume will manufacture in simulation on defined time. When the count of the machines is not suitable, then it increases the correction coefficient in defined height. The third part of this module determines machine standby for a group of products verifies via simulation. We know two types of machine standby and that cold and hot standby. Therefore, the third part of the module determines which type of standby will be used for the group of products. The next function this part is that the machines determined for a group of products will assign toward real machines in a defined system. In case that each machine of the products group was assigned is possible adding next product into the group. Otherwise, we must replace the last adding product. The final family of products is created on the base of adding and replacing products into gro[Đ]ups, where the final group fulfill all condition. The conditions are verified in the MODULE FOR FINAL CONFIGURATION OF PRODUCTS FAMILY.

This module verifies two conditions. Firstly, the counts of assign machine are lower or equal the counts of machines needed for a family of products. When the result of this condition is "lower", then the last adding product will be replacing. However, if the result of these conditions is "equal", we apply the second condition. The counts of machines needed for a family of products is lower or equal the count of all machines in the system. When the result of this condition is "lower", then we can add a new product into the group of products.
The last three modules in the block diagram are only a vision for additional continuing of this methodology. The modules contain a vision for the design of a complex system based on describing the methodology, simulation and using the multiagent logistic system. The described methodology can be used as a base for complex systems for design and optimization of new generation reconfigurable manufacturing lines.[3]

3. CONCLUSIONS

The article introduction describes the problems of current production systems that face a number of challenges related to the globalized market and the need to customize products. One of the new system concepts that can be the starting point for solving multiple problem areas are reconfigurable manufacturing systems [4]. Therefore, the solution of the problems of current production systems can be a gradual implementation of these characteristics into the present systems. In this article was introduced the methodology for designing production lines via characteristics of reconfigurability [5]. In this article was elaborately describe each module this methodology and recommendation for the next research in this area.

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-16-0488

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Business processes, Simulation model, Simulation,

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IMPROVING BUSINESS PROCESSES IN PRINTING COMPANY BY USING SIMULATION TOOLS

Abstract

The article describes how to improve business processes by using modelling and simulation tools. A dynamic business environment requires continuous improvement of business processes. By using process improvement tools, the enterprise gains insight into ongoing processes, which is the basic requirement for a planned change. The simulation tools provide professionals with the opportunity to build variants of the future organization of processes that are expected to deliver higher business performance. Using modelling tools, it is possible to describe and create the current map of the monitored processes. By introducing a change in processes, the simulation tool enables the future development of the key performance indicators monitored. In the present paper, the authors present the use of a tool for modelling and simulation of processes, where they address the role of improving the business processes of the company dealing with the production of books, magazines, paper packaging and promotional materials.

1. INTRODUCTION

In nowadays, companies are still looking for new ways, how increase productivity and profits. Most often, new technologies and devices are purchased, or different methods and standards are implemented in companies, allowing them to reduce production time and increase production. Another less-used option is improving business processes. For example, if an enterprise can communicate more quickly and flexibly with a customer and better meet his requirements for the price, it can deliver more orders and better fill own production capacity. In printing industry, the speed of internal communication is as important as production itself [2].Often, customers are required to deliver the chosen product to the market at a precise date, in a short time horizon, and therefore a fast start of production is required [4]. Also, the book industry is specific because most of the customers are represented by publishers. These publishers send customer requests into multiple companies, and

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the one who responds fastest and offers the best price gets the offer. In order to quickly send an offer and then start production, it is therefore necessary that all support processes be without unnecessary downtime and as short as possible [3]. Therefore, there is a need to improving the business processes in selected company. This improvement concerns the high number of departments and staff, which is why the company required simulation. The proposal for improvement is offered by the company itself, which wants to prove the merits of this proposal by simulation to the owners of the company [5]. Simulation is a good tool for testing required changes in businesses. It is mainly used for financial or time-consuming changes. Research proves their suitability at various departments of the enterprise [1].

2. CURRENT STATE IN COMPANY

The current state of business processes in the company is at an insufficient level, the processes take a long time, and the information flow is unnecessarily complicated due to the large number of departments. Because a large number of people work with the necessary information while processing the order, communication noise is generated. Necessary information is recorded in bad places or is duplicated, outdated or not enrolled at all, and because of the large number of people it is not possible to determine responsibility for internal complaints. These complaints arise if there is a discrepancy between the customer's requirements and the information entered in the technology card. Workers in manufacturing do not know how to produce properly if the data they own are wrong. All these deficiencies cause damages to the company in thousands of €. The process of processing the demand goes through the departments and employees e.g. see Tab.1. Employees were assigned an hourly salary to serve for the economic evaluation of the proposal. All data was discussed by the Personnel Department manager.

Tab.1. Organizational structure

Department	Employee	Quantity	Income per hour
Sales	Area Sales Manager	3	10 €
	Key Account Manager	2	9 €
	Dealer	17	8 €
Pricing	Manager	1	10 €
	Employee	4	8 €
Planning	Manager	2	9 €
	Schemer	2	8 €
Logistics	Manager	1	10 €
	Employee	2	9 €
Technology	Manager	1	11 €
	Employee	3	9 €
Data preparation	Manager	2	9 €
	Employee	7	7 €

All business processes were recorded and divided into responsible departments. Responsible staff has determined the duration of these processes. For more accurate input data, these times were written by **triangular distribution**. This distribution best reflects differences in the types of orders and abilities of employees. The company also has new employees who cannot carry out their activities as quickly as long-term employees. Contracts are also of a different nature, so the processes must have a different duration too. Another necessary data for simulation model is the number of entry demands and contracts. The company average gets **900** demands per month, but only 40% of them will company receive like contracts. This fact has been incorporated into the simulation setup so that the simulation model has been the most appropriate copy of the real state.

3. CREATING SIMULATION MODEL

After reviewing all the tracking process data, process modeling by QPR ProcessGuide software will be followed. Software shows the processes by using flowcharts. The simulation model was filled with data about the individual processes, how they are followed and how long employees perform them. Using Table 1, we completed the simulation model with the necessary data on individual worker. Information such as the number of employees per unit, hourly wage, and process responsibility will help us evaluate the results of the simulation.
The simulation model was started after entering the input data and setting the number of **activations** to 250, which is equal to the weekly average of the queries. It was also set that out of these 250 queries, only 40% would be accepted as a contract. Table 2 shows processing time, in simple and in hard contract.

Tab. 2. Processing time in actual state

Type	Processing time
Minimum	0d 7:28:05
Maximum	3d 8:46:56
Average	**1d 4:24:03**

The simulation results for actual state in company evaluated the cost of workers in the amount **21 280€.** The results from simulation show the obvious shortcomings of the high weekly burden on employees in all departments. These drawbacks lead to the above errors, such as recorded information in bad places or duplicating information, outdated or not enrolled at all.

4. SOLUTION DESIGN

An enterprise has already proposed a solution that is based on a new job position. This job position will be name project manager, and will be performed by employees from all departments. Also dealers will be divided into senior and junior salesman. Senior will only travel around important customers, and maintain good relations with them. Junior salesman will be writing and preparing every necessary information from customers to company.

Tab. 3. Processing time for solution

Type	Processing time
Minimum	0d 5:18:57
Maximum	3d 1:55:08
Average	**1d 1:54:20**

Project manager will be substituting pricing, planning and logistic department. This change will removed information noise, and necessary information will be clearer.

In the case of internal complaints, it will also be easier to look for the responsible employee. For the correct comparison of results, the solution model has the same number of activations, like actual simulation model. 250 activations exactly match the weekly numbers of requests from customers. The result is improved and simplified flowchart with fewer departments. The design shows employees have more time and they are not overloaded more. In solution only employees who are overloading are technology employees. This department must be optimized in the near future. The simulation results for solution model evaluated the cost of workers in the amount **18 175** €.
The simulation of the proposal proved that the management's proposal is well-founded and can save **15%** of the salary costs. It will also reduce the processing time of **3hours** on average per contract. In year 2016, company have 4400 contracts, so they can save **12 000 hours** with this solution. The proposal should also prevent the creation of internal complaints in the enterprise that have emerged as a result of information noise

5. CONCLUSIONS

Solving these problems requires a lot of time and employees energy. Several tools have been developed to facilitate and streamline this activity. QPR ProcessGuide is a simple and flexible tool that allows you to create a model to keep track of problems and refinements. Through graphs and spreadsheets, it enables clear and aggregate analysis. Everyone in an enterprise can access intranet models, modify them to improve communication within an organization, and significantly reduce the amount of work needed to build communications material. It provides insight into the administrative processes where the hidden wastage of society often occurs. To sum up, we showed that simulation has substantiation in improving business processes. And can evaluate the proposed changes before they are introduced. This is important factor, when these changes affect employees. Also, more research is needed to better understand the system dynamics. We think that the simulation software QPR ProcessGuide, will allow us conducting such future research.

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-16-0488

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Title:	InvEnt 2019: Industrial Engineering – Invention for Enterprise
Kind of publication:	Proceedings
Publisher:	Wydawnictwo Akademii Techniczno-Humnistycznej w Bielsku-Białej, Willowa 2, 43-309 Bielsko-Biała. Tel.: 033 8279 268
Date of issue:	June 2019
Proceedings maker:	Ing. Róbert Hodoň, Ing. Blanka Horváthová
Cover and Design:	Ing. Martin Gašo
Editor-in-chief of Publishing:	doc. Ing. Martin Krajčovič, PhD.
Edition:	1st Edition
Range:	140 Pages
Link:	www.priemyselneinzinierstvo.sk
Font:	Times New Roman

ISBN 978-83-66249-18-9