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CONTENTS

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Digital Twin, manufacturing, digital factory, simulation

Ivan ANTONIUK[1], Ladislav PAPÁNEK[2], Vsevolod BASTIUCHENKO[3], Martin KRAJČOVIČ[4]

DIGITAL TWIN PRODUCTION SCHEDULING BASED ON SIMULATION

Abstract

Custom production has growing potential today, and soon, custom manufacturing will be a critical opportunity to meet the onslaught of competition and meet demand for most industries. Such a trend requires major changes, whether in the material or information structure of companies. Also, conventional planning methods lose their effectiveness as they focus on a larger time horizon or mass production.

1. INTRODUCTION

With the development of intelligent manufacturing, companies are using more and more new information technologies, such as the Internet of Things (IoT), cloud computing, Big Data, and artificial intelligence, to improve production efficiency and flexibility. New manufacturing models, such as cloud manufacturing, green manufacturing, and service-oriented manufacturing, are evolving to meet the new manufacturing requirements of socialization, personalization, service, and intelligence. Today, scheduling plays an important role in custom manufacturing. In intelligent manufacturing, the new meanings of production planning are listed below [1]:

1. Real-time manufacturing and flexibility are two goals of intelligent manufacturing. Due to the large number of operations, the complex relationship of cooperation, the strong continuity of production, the rapid change of circumstances in modern industrial

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enterprises and the failure of certain parts often affect the operation of the entire production system. Early response to dynamic events in production planning is therefore becoming an important issue that needs to be addressed urgently.

2. Uncertain events usually occur in the production process, which could cause an information asymmetry between the actual production process and the proposed schedule and thus affect the achievement of the goal. Static workshop planning results in a large deviation between the designed schedule and the actual production process, serious waste of production resources and low production efficiency. Dynamic planning strategies should therefore be considered in production.

   Based on the above facts, the idea of creating a system of short-term planning through a digital twin based on dynamic simulations and with real-time data collection arises.

2. CONCEPT OF DIGITAL TWIN PRODUCTION SCHEDULING SYSTEM BASED ON SIMULATION

The DT-based custom manufacturing planning architecture consists of two parts: physical space and virtual space, as shown in the figure. These two parts communicate with each other through communication channels. In virtual space, scheduling data can be obtained from a monitored resources in physical space, such as equipment, staff, MES, ERP, and so on. Planning strategies can be obtained and simulated using planning models and algorithms with the collected source data. The final verified schedule is sent back to the physical space for execution. In the physical space, the plan is divided into individual jobs, machine distribution, operator distribution and material transport, etc…

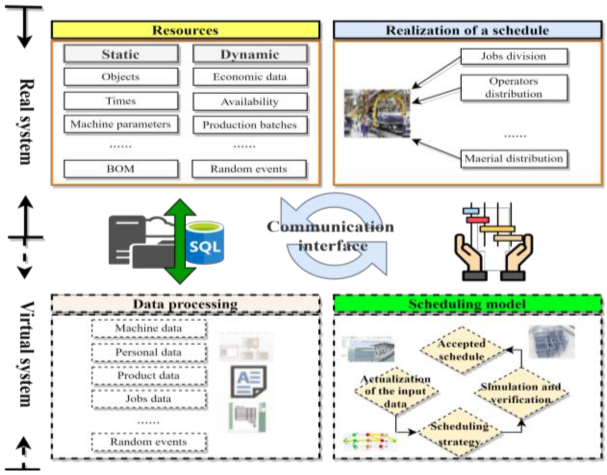

Fig. 1 Digital twin scheduling system architecture

With this new planning mechanism, it is possible, on the one hand, to perform statistics and data modelling with the relevant parameters (processing time, level of staff knowledge, costs, energy consumption, etc.).[3] Accurate distribution of planning parameters can be achieved by continuous interactive communication between the virtual and real environment. On the other hand, by exchanging data between the two premises, it is possible to analyse various information on production failures and adjust the corresponding restrictions. Therefore, it is possible to update the schedule and send it back to production to ensure a timely response to change and keep production flowing.[4]

3. CASE STUDY

Verification of the designed system was realized in the company, which manufactures roof windows. It is a custom production where each product that enters production is assigned to a specific customer and can be configured in any way when ordering.
Production consists of 17 workplaces and each product passes through process as one piece, which is mounted on the underrun AGV. After each operation, based on current conditions, it is decided which workplace will be the next for job processing.
To monitoring and collecting data from production, it was necessary to cover 2 production halls with an area of 2,304 m2. This monitoring system uses 12 direct UWB anchors, 40 personal RTLS tags, 17 tags for tracking AGV trucks and 2 tags for forklift pallet trucks. The proposed production system does not contain common machines, the measurement of real cycle times of workplaces was realised by identifying the time of remaining of the job at a specific workplace using the RTLS system. In this way, accurate real-time localization and data collection has been achieved and all data is integrated with production, Track and Trace (TaT) and Tecnomatix Plant Simulation software [2]. In addition to the data from the monitoring system, a connection to the SAP corporate ERP information system is also set up. The whole data system works with the support of the Digital Twin software platform.

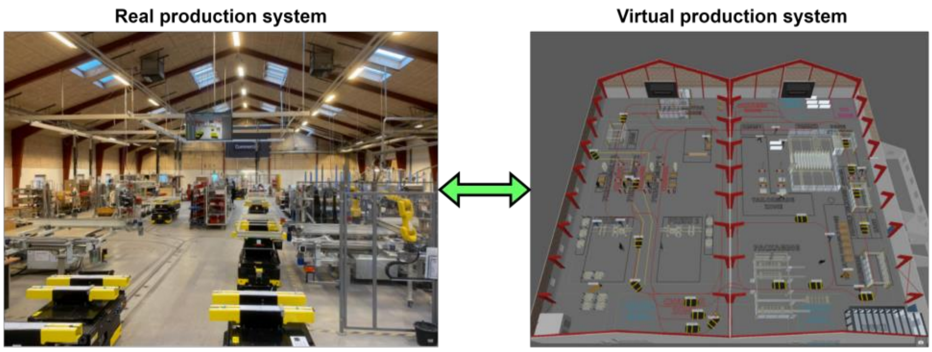

Fig. 2 Implemented digital twin of the proposed system

3.1. Results

When creating experiments, it was a matter of creating a schedule without its initial variant, this means that the schedule was created gradually during the simulation run. Therefore, it is not possible to evaluate whether any improvements have occurred, but each variant of the schedule was evaluated based on the calculation of the sanction function. Within the performed experiments, all variants of the schedule (Tab. 1) were feasible and acceptable, but the schedule with the best evaluation of the sanction function is applied to the production.

Tab. 1 Results of the experiments

	Exp.1	Exp.2	Exp.3	Exp.4
Dispatching rules	CR, bottom to up	CR, up to bottom	FIFO, up to bottom	FIFO, bottom to up
Start [hh:mm:ss]	5:45:00	5:45:00	5:45:00	5:45:00
End [hh:mm:ss]	14:08:00	14:09:00	14:03:00	14:04:00
Time remaining	1:37:00	1:36:00	1:42:00	1:41:00
Lead time [hh:mm:ss]	8:23:00	8:24:00	8:18:00	8:19:00
Produced [Pcs]	223	223	223	223
Acceptable schedule?	Yes	Yes	Yes	Yes
Evaluation [€]	26464	26450	26533	26519

4. CONCLUSION

The article focused on the Digital Twin-based scheduling through dynamic simulation. The conceptual design of the scheduling system was described in Chapter 2. The whole design was successfully verified on a real example in a production system.

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Quick Response Manufacturing; megatrends; process mining; customer

Vsevolod BASTIUCHENKO[1], Martin KRAJČOVIČ[2], Vladimíra BIŇASOVÁ[3], Marta KASAJOVÁ[4]

QUICK RESPONSE MANUFACTURING

Abstract
Today's highly competitive business environment forces companies to work closely with their trading partners and deliver the right products and services in their supply chain at the right time, with the right quality and at an affordable cost. One of the key success factors in this highly volatile business environment is production planning. Production planning is the process of ensuring that production runs smoothly and on time.

1. INTRODUCTION

Quick Response Manufacturing (QRM) provides a proven set of principles and tools to reduce production lead times as well as technical lead times. QRM helps selected companies reduce lead times by more than 80%, reduce costs by 20-40% and significantly increase market share [1]. Fast-growing trends are no longer anything special nowadays. The trend is formed by consumer requirements, constant technical development, the effort of small, medium and large companies to be successful and competitive. Customers are increasingly demanding highly customized products and short delivery times. Companies that are responding to this challenge have seen growth in profitability and market share. [2]. The key to successful implementation in a challenging competitive environment is to reduce lead times to eliminate waste such as shipping, excess inventory and high costs. [3]. QRM is an enterprise-wide strategy that reduces lead times and monitors the reduction of lead times in all operational aspects. Both internally and externally. From the customer's point of view, QRM is specific and means a quick response to customer requirements through rapid design and rapid production of a product designed based on these requirements. This is an external aspect of QRM. Furthermore, in connection with the company's operational economy, QRM focuses on reducing the lead times of all tasks. This is an internal aspect of QRM.

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2. LITERATURE REVIEW

If we talk about global trends, the first is the growth of small and medium-sized companies. For these companies, the agility strategy is the most suitable because they not only use mass production for products of the same type, but also produce smaller volumes of different types of products. Of course, they focus on the needs of different customers to keep them. Unlike large companies, small and medium-sized enterprises are more agile and better able to improve. [4]
Another trend is the emphasis on local production. This trend was evident during COVID-19 measures. [5]. For example, the automotive and electrical industries imported processors across the ocean and are now forced to build local capacity. [6]. American industry is trying to build and supply mainly its own production. In other words, local production, where subcontractors are in the local state or region, is also cheaper in the long run, although relatively initially they can be more expensive. [7]. As the risks of long-distance transport increase, so do problems with quality or reverse logistics (sending back for repairs or sending failures back is more difficult) [8].

3. METHODOLOGY

QRM is a company-wide strategy in which the main goal is to reduce production preparation time and production itself. This approach uses four basic concepts (pillars):
1. The power of time: Complete replacement of traditional cost-oriented efficiency goals and use of QRM time goals, which means focusing on overall time reduction. Traditional manufacturing companies focus on cost reduction strategies, resulting in a high degree of work specialization and a hierarchical departmental structure. QRM shows why this traditional setting has a negative impact on delivery times while generating a lot of hidden costs.
2. Organizational Structure: QRM shows the principles and tools for creating production cells, for companies that produce a wide range of products in small batches. They are designed according to Focused Target Marketing Segment (FTMS), where shorter lead times provide critical advantages to the business. They are applied in sales, production and administration.
3. System dynamics: The cellular structure of QRM is complemented by an understanding of system dynamics specifically tailored for high-mix environments. Application of common principles of system dynamics leads to better capacity planning and optimized batch sizes just to achieve short lead times.
4. Enterprise wide application: QRM applies the principles of time-based management to all parts of the organization including office operations, purchasing, production management, supply chain and new product introduction.

4. RESULTS USING DATA TO UNDERSTAND PROCESSES

One of the main ideas of a QRM strategy is to reduce the throughput time of manufacturing, administrative or enterprise-wide global processes. An important factor is the proper understanding and identification of the value stream in the enterprise. The classical method of data collection is based on tracking and recording all times, examining production documentation and analysis. Tools such as VSM (Value Stream Mapping) and MCT (Manufacturing Critical-path Time) help us to represent the flow of business operations and their duration. [3] Nowadays, there are modern tools and methods that simplify the work of industrial engineers. They offer very fast and high-quality results, specifically in the way of Process Mining. Process Mining focuses on visualizing and analyzing processes based on event logs. In general, event logs and process logs are based on enterprise information technology (IT). During the production process, data about the production process (wizard) is recorded on workstations. If the individual process steps from the start point to the end point are correctly traced and logged, their positions in the layout are obtained and confirmed with an accurate time stamp. Subsequently, in the database, it is possible to filter specific sections of the material and production flows, analyse them and understand them individually.

Process data mining techniques are often used when there is no official process description that can be obtained by other means, or when the quality of existing documentation is questionable. An example of areas of application of data mining techniques:

- Auditing the production management system and material flows,
- Analysis of transaction records from an ERP system (Enterprise Resource Planning system),
- Analysis of electronic records for materials, semi-finished and finished goods.

They can also be used to extract models describing processes. Also for comparison with a previous model or observed reality fitted to some prospective or descriptive model.

4.1. Sequence of steps when starting to work with the software

There is a specific sequence of steps to follow when you start working with the Disco software:

1. Pull the information in the Excel document view from the database systems. This document would have in it a registered value stream with identification number, time stamp, start and finish of each of the streams, appointment of technical or human resources, of course related to the other named items. (Fig.1)

	B	C	D	E	F
1	Start Timestamp	Complete Timestan	Activity	Resource	Role
2	2011/02/16 14:31	2011/02/16 15:23:0	Create Purchase Requisition	Nico Ojenbeer	Requester
3	2011/02/17 09:34	2011/02/17 09:40:0	Analyze Purchase Requisition	Maris Freeman	Requester Manager
4	2011/02/17 21:29	2011/02/17 21:52:0	Amend Purchase Requisition	Elvira Lores	Requester
5	2011/02/18 17:24	2011/02/18 17:30:0	Analyze Purchase Requisition	Heinz Gutschmidt	Requester Manager
6	2011/02/18 17:36	2011/02/18 17:38:0	Create Request for Quotation Requester	Francis Odell	Requester Manager
7	2011/02/22 09:34	2011/02/22 09:58:0	Analyze Request for Quotation	Magdalena Predutta	Purchasing Agent
8	2011/02/22 10:50	2011/02/22 11:03:0	Amend Request for Quotation Requester	Penn Osterwalder	Requester Manager
9	2011/02/28 08:10	2011/02/28 08:34:0	Analyze Request for Quotation	Francois de Perrier	Purchasing Agent
10	2011/05/17 06:31	2011/05/17 07:08:0	Create Purchase Requisition	Immanuel Karagianni	Requester
11	2011/05/17 09:58	2011/05/17 10:06:0	Create Request for Quotation Requester	Esmana Liubiata	Requester
12	2011/05/18 19:30	2011/05/18 19:56:0	Analyze Request for Quotation	Francois de Perrier	Purchasing Agent
13	2011/05/18 23:46	2011/05/18 23:59:0	Send Request for Quotation to Supplier	Magdalena Predutta	Purchasing Agent
14	2011/05/19 03:44	2011/05/19 08:31:0	Create Quotation comparison Map	Francois de Perrier	Purchasing Agent
15	2011/05/19 15:38	2011/05/19 15:52:0	Analyze Quotation comparison Map	Kim Passa	Requester
16	2011/05/19 15:52	2011/05/19 15:52:0	Choose best option	Anna Kaufmann	Requester
17	2011/05/20 23:31	2011/05/21 09:22:0	Settle conditions with supplier	Magdalena Predutta	Purchasing Agent
18	2011/05/21 18:48	2011/05/21 18:59:0	Create Purchase Order	Francois de Perrier	Purchasing Agent
19	2011/05/22 11:33	2011/05/22 11:44:0	Confirm Purchase Order	Esmeralda Clay	Supplier
20	2011/05/23 05:32	2011/05/24 13:46:0	Deliver Goods Services	Esmeralda Clay	Supplier
21	2011/05/24 20:59	2011/05/24 21:00:0	Release Purchase Order	Kim Passa	Requester
22	2011/05/26 07:41	2011/05/26 07:42:0	Approve Purchase Order for payment	Karel de Groot	Purchasing Agent
23	2011/05/28 01:11	2011/05/28 01:11:0	Send invoice	Kiu Kan	Supplier
24	2011/05/28 15:28	2011/05/28 15:28:0	Authorize Supplier's Invoice payment	Pedro Alvares	Financial Manager

Fig.1. Input data example

2. Load input data (Excel) into Disco software. Then mark the columns according to certain groups offered by the software tool (Case ID, Start/complete timestamps, Actvities, Resourses, Roles).

3. Press the "Start Import" button and wait for the software to prepare and load the data. As a result, we get a clearly generated process map of the actual status, resource and process utilization and detailed defined run times.

After exporting the data to the software environment, we have the possibility to use many useful tools. The value flow sequence we see on the first tab represents a process map. In simple words, the software can create a given map based on the output data of the database systems described above.

5. CONCLUSION

One of the main ideas of QRM is to reduce throughput times, which means fast execution of specific processes. True Process Mining mainly focuses on defining these processes and their time requirements. Therefore, the given method is useful for an industrial engineer because he doesn't have to wait with a watch and take snapshots somewhere in the purchasing department or in production. He just needs to pull the necessary information from the system database sources and use process mining tools like Disco to process even a very large dataset. In addition to that, proof mine all the through times and name the wastage. In some ideal example, this should result in a constant state of resources and values. The volatility or variability of the processes in the enterprise is normalized, because when there are many orders, for example even between departments, it means that someone is waiting a long time for his order to be processed, and this puts a strain on and disrupts the smooth process. In the case where production is seasonal, it means for the enterprise that they need to adapt to the capacities that the market demands from them.

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Industrial symbiosis, resource, waste management system, efficiency

Vladimíra BIŇASOVÁ[1], Branislav MIČIETA[2], Vsevolod BASTIUCHENKO[3], Marta KASAJOVÁ[4]

THE POTENTIAL OF INDUSTRIAL SYMBIOSIS

Abstract
Industrial Symbiosis is currently a well-discussed concept in developing ecoindustries, which aims at maximizing the resources conservation and emission reductions through exchange of by-products between industries and also is a form of brokering to bring companies together in innovative collaborations, finding ways to use the waste from one as raw materials for another.

1. INTRODUCTION

The term "industrial symbiosis" was coined in the small town of Kalundborg in Denmark. This region has a dense and well-developed network of interactive companies. In Kalundborg, a partnership has been established between actors such as oil refinery, power plant, pharmaceutical company, gypsum board producer. It was necessary to ensure an efficient system of mutual sharing of groundwater, surface water and wastewater. In addition to the mentioned water sources, among which we can also include steam, it was also necessary to implement the mutual sharing of different types of fuels and a diverse portfolio of by-products, which will be used in the partner company as input raw materials in production processes.

2. LITERATURE REVIEW

Industrial symbiosis also deals with the study of technical and regulatory aspects that may occur in different places and cause the facilitation or reduction of industrial symbiosis. Finally, it should be mentioned that industrial symbiosis is considering it future direction based on current and historical experience. Conservation of resources in Western countries is important, but even more important is the conservation of resources in developing countries. Resources in these countries are already very scarce [1]. Key Industrial Programs symbiosis in Chinese industrial parks, are currently beginning to benefit from cooperation with the State Environmental Protection Administration and the National Development Research Council

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[2] [3]. The Resource Optimization Initiative, based in India, has invented a systems approach to industrial ecology that promotes an understanding of the potential between business sharing. [4]. Industrial symbiosis is helping to mitigate some of the effects of global warming. This knowledge is based on the water, energy and materials cycle, reducing the consumption of fossil fuels and facilitating the transport of materials over long distances [5]. As a result of these activities, the private sector has taken on an industrial symbiosis as a means of increasing security and resource availability. Logically, this supports the idea of resource productivity, promoted by the World Trade Council for Sustainable Development and its affiliates. Hybrid public-private organizations such as NISP (National Industrial Symbiosis Program), can facilitate the growth of green industrial networks by bridging the information and cost barriers that many projects face [6]. On the one hand, the public is already concerned about development engineering, which is involved in material exchanges that bring the remnants of one industry to different industries. On the other hand, the specification of the region in terms of water scarcity and the rarity of some materials accelerate the trend towards cyclicality and reuse [7].

3. METHODOLOGY

Selected company providing complete services in the production and development of complex electro-mechanical systems for OEM customers operating in the market segment of low-volume and high-quality products. The company offers its clients an optimal system solution from development through material management, production and logistics to after-sales services. Elements of industrial symbiosis include:

- incoming energy and material,
- life cycle perspective,
- chaining,
- closing the loop**,**
- material flow monitoring
- industrial supplies,
- input and output adjustment,
- stakeholder processes,
- material budgets.

4. RESULTS

This chapter deals with the design of the use of industrial symbiosis in a selected company, which is focused on saving resources in the production process.

Problem area 1:
The company does not implement the theoretical basis of industrial symbiosis in the management of produced waste, does not have established principles and does not use the current possibilities of industrial symbiosis.
Proposed solution 1:
Based on the study of theoretical knowledge and consultation in industrial practice, principles for the effective implementation of industrial symbiosis in companies were proposed.

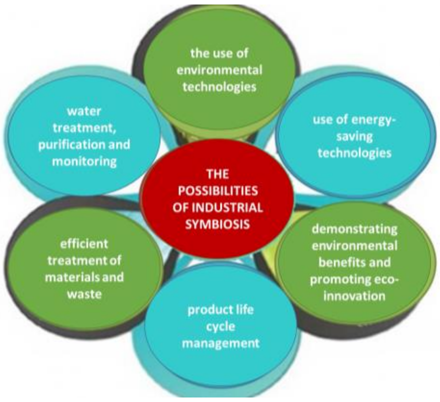

Fig. 1. Principles for the use of industrial symbiosis in companies

As shown in Fig. 1, a company that wants to be active in the direction of industrial symbiosis, as a modern tool of industrial ecology, must focus its activities on effective implementation of the proposed principles of industrial symbiosis:

- use of energy-saving technologies, compared to conventional technologies, energy-saving technologies use the braking energy of the engine, which is uselessly converted into heat in conventional technology.
- the use of environmental technologies, which have the task of reducing costs and at the same time supporting the increase of competitiveness by reducing the consumption of energy and raw materials, as a result of which the production of unwanted emissions and waste decreases.
- water treatment, purification and monitoring, industrial wastewater treatment is a necessity today. Wastewater coming from industrial plants has a significant effect on the quality of groundwater and water in watercourses. convert polluted water into water that can be further used in industrial production.
- efficient treatment of materials and waste, which should be a priority for advanced enterprises. Minerals occur in nature in limited quantities and therefore need to be handled efficiently.
- product life cycle management by the manufacturer, through a new concept that aims at zero-waste production. This concept opens up an opportunity for a new kind of business: traders will not only sell products, but will also provide the services that belong to them.
- demonstrating environmental benefits and promoting eco-innovation that reduces material, energy requirements, uses alternative energy sources and promotes sustainable consumption

Problem area 2:

- None of the generated waste is further processed as an input to a different production process carried out by the company. The company also does not have an established business relationship that would be contractually secured with an external company that buys the generated waste. In terms of industrial symbiosis, it is possible to reuse the waste as a raw material after purchasing the waste and its subsequent recycling. Such a contractual relationship between the business relationship can bring economic benefits to the selected business.

Proposed solution 2:
The basic scheme of the sequence of waste management steps implemented in the company can be extended. Through this scheme, it is possible to implement waste management in accordance with the principles of industrial symbiosis. The original scheme has a direct structure and its orientation is aimed at disposing of waste in the simplest legal way possible.

5. CONCLUSION

One of the main ideas of QRM is to reduce throughput times, which means fast execution of specific processes. True Process Mining mainly focuses on defining these processes and their time requirements. Therefore, the given method is useful for an industrial engineer because he doesn't have to wait with a watch and take snapshots somewhere in the purchasing department or in production. He just needs to pull the necessary information from the system database sources and use process mining tools like Disco to process even a very large dataset. In addition to that, proof

ACKNOWLEDGEMENTS

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3D printing, technical service, spare parts

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THE UTILISATION OF 3D PRINTING POSSIBILITIES IN TECHNICAL SERVICE

Abstract
This article deals with the possibilities of using 3D printing in the company in the technical service. 3D printing is one of the fast-developing, most accessible technologies connected with software solutions and is possible to use in industrial practice. 3D printing brings a huge number of benefits, and it opens the way for the improvement of production and maintenance processes. Thanks to the rapid replacement of spare parts with 3D printing, production will be interrupted for a shorter time during the breakdown, as well as unnecessary stocks in warehouses.

1. INTRODUCTION

Factory of the Future is described in many kinds of literature as a future-oriented manufacturing company that primarily uses the most advanced innovative, digital, disruptive, exponential technologies. These technologies are then used to develop and implement intelligent, green and sustainable processes. To ensure this process, available materials, information, energy and company managers put their trust in innovative business models that aim to strengthen their company's position in the market. As a result, customers expect the products they buy to have high added value, and companies must respond flexibly to their increasingly specific needs. The intensively increasing numbers of individual customers demanding to modify the details of their products continuously until the final point of the assembly want to be present at the birth of their personalized products [1]. The Factories of the Future provides software tools that can help develop and adapt to the demanding requirements of the market, workers, customers and the position of companies in the global market. In this article, we will deal with a specific area of the company, which is technical service.

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2. 3D PRINT

3D printing is currently one of the dynamically developing technologies within the Industry 4.0 concept and the Japanese Company 5.0 concept. Defining Society 1.0 as the hunter-gatherer stage of human development, we have now passed through the agrarian and industrial stages, Society 2.0 and 3.0, and are moving beyond the information age, Society 4.0 [8]. The Japanese government introduced this concept, Company 5.0, in 2016 and used technologies from the Industry 4.0 concept to improve people's work environment [6]. Additive production technologies have made significant progress in recent years and a shift towards its common use in some selected areas (prototypes, pressure- and environment-friendly final products, etc.). Additive manufacturing is a process in which objects are produced from a digital 3D-CAD model by bonding metal powder layer-by-layer [4]. In this way, even products with complex structures, shapes, and different sizes can be "printed". Therefore, more and more factories, mostly abroad, are testing the use of additive production to print final products for customers. From the point of view of the use of 3D printing in the technical service, these are spare parts.

2.1. 3D printing and spare parts management

The most widespread use of 3D printing today is still only in the preparation and production of prototypes of spare parts, components and products. Therefore, spare parts management is emerging or constantly improving in companies. The management of spare parts in factories has come up with a long list of challenges in recent years; such as high costs for storage, material, logistics, overproduction caused by the minimum volume of purchases and last but not least, these are also the so-called standard and predominant long waiting times. Other problems are obscured machines, insufficient maintenance, improper handling of tools, etc. From the point of view of spare parts, suppliers often no longer offer and do not have the required spare part available, such as parts needed for trains, buses, large specialized machines in factories, or other machines and handling equipment used in factories in the production or logistics process. Some of these facilities have been in operation for several decades, so if no spare parts are needed, the operation of these facilities is usually interrupted or cancelled, leading to their decommissioning.

In the traditional setting of production systems, if the device or its part breaks down, employees must reach stock or order a new spare part, which can take several days to weeks. With 3D printing technology, it is possible to produce the necessary part in the so-called in-house within from minutes to hours (depending on the size and complexity of the spare part). In addition to time savings in the factory's production and their technical service departments, they also save on warehouse space.

Spare parts made of plastic or metal can be produced on request using a 3D printer without the use of tools and in the exact required quantity without a minimum purchase volume, with reduced delivery time. The factory thus avoids unnecessary overproduction. The advantage is also the paperless production because the model for printing is uploaded to the 3D printer directly from a computer or, e.g. via an SD card.

2.2 Description of selected problems with spare parts in the technical service

As part of the solution of a grant project at the University of Žilina called 3D printing of spare parts in the technical service, several problems were solved in the given area. The selected problem solved at the Department of Industrial Engineering was the creation of a methodology or sequence of steps for the implementation of 3D printing of spare parts in the technical service, later with its verification in a selected factory. At present, 3D printing is still a unique technology in factories and technical service departments. It can be found in other areas of factories, such as marketing, promotional items, etc. Many factories often have only critical spare parts in the warehouse, and other spare parts are primarily delivered within a few hours or on most days. However, sometimes it is necessary to deliver a spare part that is not in the factory in a very short time (usually 24-48 hours). Damaged or worn parts are modeled into the 3D model and then they can be produce in the required quantities from the selected material. The materials can be replaced with plastics, aluminum, or even some types of steel. Spare parts can be produced very efficiently in 3D printing, as it is a highly flexible technology with the lowest input costs in piece production of all available technologies.

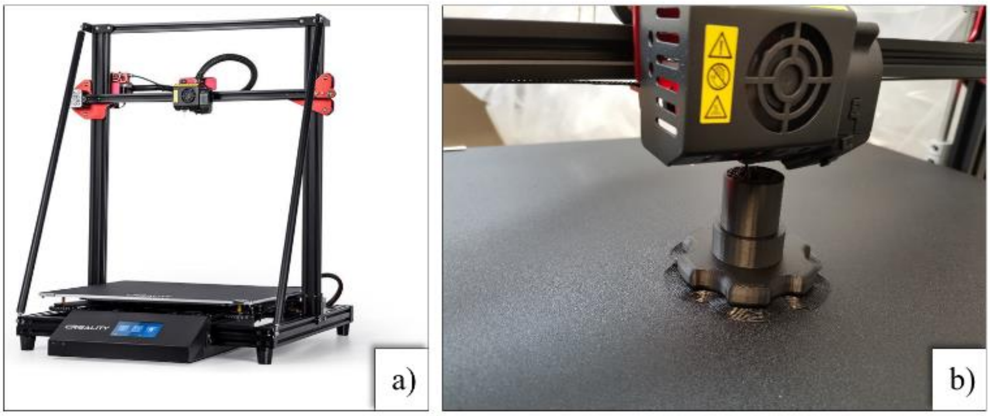

Fig.1. Creality CR-10 Max the 3D printer (a) [7], Process of 3D printing (b) (main author)

At the Department of Industrial Engineering, a Creality CR-10 Max the 3D printer is used for research in laboratory conditions (Fig.1. a)). For reasons of sustainability and environment, PLA printing material was chosen for the printing of spare parts (Fig.1. b)). Material PLA (Polylactic Acid) is the easiest to manufacture with high strength. However, it is brittle and has low heat resistance.

3. COMPONENT REPLACEMENT USING 3D PRINTING

A description of the basic steps of how it is possible to replace a damaged spare part with the aid of 3D printing and which includes the 3D printing process itself is shown in Fig.2.

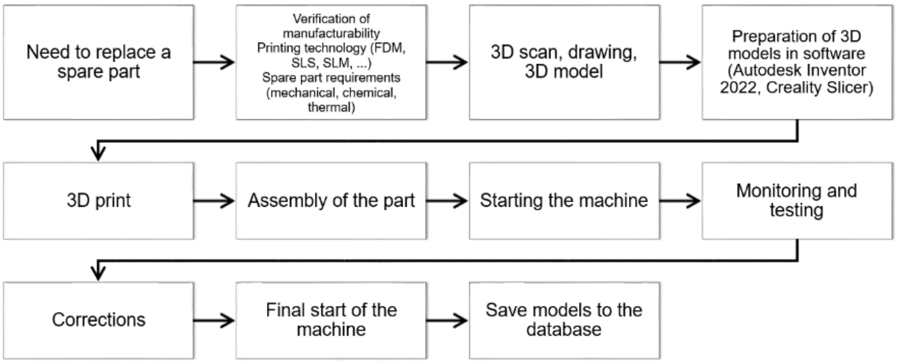

Fig.2. Methodical steps of damaged part replacement steps using 3D printing (main author)

A detailed description of the methodology:

- Step 1: The need arose to replace the replacement spare part.
- Step 2: In this step, it is necessary to address the verification of the manufacturability of the spare part, the choice of printing technology and define the mechanical, chemical and thermal requirements for the spare part. Based on the feasibility study, it can be assumed that the required spare part can be manufactured using 3D printing.
- Step 3: It is necessary to determine if a drawing of the damaged part is available in 2D or 3D view. If a drawing is not available, the required part must be scanned. It is faster than measuring it manually and creating a new model on the computer. The result of the second step is a 3D model of the part.
- Step 4: It is necessary to create a file with the extension '.stl - stereolithography'. After creating such a file, it is possible to import it into the environment of specialized software, so-called slicer. An important element is to define the print quality and thickness of the applied layer.
- Step 5: The 3D printing of the product itself takes place. The duration of 3D printing is adjustable, individual. It all depends on the print quality and the thickness of the applied layer. The time can range from a few tens of minutes to tens of hours. The fourth step also includes the so-called post-processing (cleaning, repair/correction, curing, surface treatment, painting/varnishing).
- Step 6: The assembly of the extruded spare part itself takes place according to the defined assembly processes.
- Step 7: A pilot start of the machine is in progress. In this step, it is necessary to pay attention to the safety of workers during the test start of the machine.
- Step 8: The machine is monitored and tested, which means empty and gradually loading the machine. Selected parameters are monitored, such as vibration, temperature, noise, unusual machine behavior, etc.
- Step 9: If necessary, the necessary corrective measures and deviations will be developed.
- Step 10: After approval by the manager, the maintenance of the machine is completed, and the machine is fully functional.

- Step 11: It is necessary to store the spare parts models and their corrections in the database for their use in the future.

Additive production will play an important role in the production of spare parts in the coming years and also in the production of classic components. During 3D printing, the material is added, and only the amount needed for the product is consumed. It is a layering of material up to the final form of a computer model of a spatial body. Changing how product development is incorporated by adding additive production is a good way to gain a competitive advantage.

4 CONCLUSION

By comparing the time required to program CNC (Computer Numeric Control) machines, labor costs, and design constraints, the use of 3D printing can halve the time required to produce a part. Advantages of using 3D print from the factory's point of view include the following:

1. more faster production of spare parts, and possibility to print only one piece of part,
2. flexible and fast production (in some cases also within 24 hours),
3. high input costs are not required (as in the case of other production technologies),
4. possible modification of the original shape of damaged parts,
5. a wide range of available filament colors and materials
6. improving the MTTR (Mean time to repair),
7. reduction of repair costs,
8. improving the OEE (Overall equipment effectiveness) indicator,
9. integration of 3D printing technology into maintenance strategies,
10. reduction of unused items in the warehouse, etc.

The described methodological sequence of steps will help, for example, companies to get an idea of the implementation of 3D printing in their processes in technical service. After testing 3D printing spare parts, the factory can even start producing some parts of the final products. Implementing 3D printing in factories is not just about the implementation itself. Moreover, it is mainly about the gradual implementation of exponential technologies with the aim of transforming the factory into a smart factory and later into a fully intelligent factory. The fundamental changes will affect not only the equipment used in logistics itself, but also the whole logistics concept will have to transform, to find its place in the ever changing environment of the Factories of the Future [2]. Companies want to gather more and more information about processes, and they want to be able to evaluate them in a quality way and make better decisions [3]. Exponential technologies are innovative technologies that are advancing at a very fast pace (greater than Moore's Law states) and usually have a positive impact on millions to billions of lives in various areas of life. It is also necessary to realize that the power of exponential technologies is not that they significantly increase something's performance but make the same performance significantly cheaper.

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Adaptative manufacturing system, production rules

Natália BURGANOVÁ[1], Patrik GRZNÁR[2]

CREATING AN ADAPTIVE MANUFACTURING SYSTEM

Abstract
The concept of adaptive production is not yet clearly defined and conceptualized. However, the general attributes of adaptability can be defined in terms of fast response, flexibility, integration, customized products, speed. The article describes the creation process of the adaptive manufacturing system using algorithm with conditons.

1. INTRODUCTION

In industrial production, customer requirements differ and lead to new products, different product variations and stages that require a departure from production and control. This requires the adaptation of the production system and its monitoring and quality control system, together with process diagnostics, which is becoming more common in every industry and demanding. Therefore, there is a need for flexible manufacturing that can successfully cope with unpredictable and constant changes in the operating environment to remain competitive. The adaptive production system is evolving as a new production paradigm beyond conventional production systems. Adaptability in manufacturing can be successfully achieved by integrating various practices that allow companies to respond quickly to change [1]. The adaptive plant aims to enable the production system at plant level to be flexible and adaptable. Adaptive manufacturing aims to improve efficiency and reduce costs in responding to changing market conditions. A characteristic feature of adaptive production is its ability to adapt, think and succeed where another production philosophy would fail.

Properly implemented adaptive manufacturing will allow manufacturers to speed up the industrial market so that companies are ahead of their competitors. They are the first on the market brings certain benefits. These benefits include creating a time gap with your competitor in the market and customer loyalty [1].

The production system can simply be considered as a collection of production rules, i.e., a condition-action pair, C => A, where the left side of each pair is a set of conditions relevant to the content of a particular database or working memory on the right is a list of stocks.

The production process starts only after all conditions are met. An adaptive production system is defined as a system that can modify its own production rules by its actions. There are three main ways to do this: by adding new rules, removing old rules, and changing existing rules.

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We use the knowledge system (KBS) to integrate data and tools, the systems solve knowledge-based problems. In fact, KBS is an intelligent computer program that is able to solve complex problems in specific areas by mimicking human expert thinking.

2. EXAMPLE OF USING PRODUCTION CONDITION

The human mind is very complex and cannot be represented by any algorithms. Nevertheless, most professionals can express their knowledge in the rules of production. All production rules consist of two parts: the IF part, which specifies the conditions that must be submitted for the application of the production rule, is called the condition, and the THEN part, which represents the appropriate action that results from the condition. Compared to other approaches, such production rules are relatively easy to create and understand.
The basic syntax of conditions is:

$$\begin{gathered} IF\ < CONDITION > \\ THEN\ < ACTION > \end{gathered}$$

In general, a rule can have multiple conditions, which are usually associated with the keywords AND (conjunction), OR (disjunction), or a combination of both.
For example:

$$\begin{gathered} IF\ < CONDITION\_1 > \\ AND\ < CONDITION\_2 > \\ \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots . \\ AND\ < CONDITION\_XY > \\ THEN\ < ACTION > \end{gathered}$$

$$\begin{gathered} IF\ < CONDITION\_1 > \\ OR\ < CONDITION\_2 > \\ \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots . \\ AND\ < CONDITION\_XY > \\ THEN\ < ACTION > \end{gathered}$$

The rule can have several actions:

$$\begin{gathered} IF\ < CONDITION > \\ THEN\ < ACTION\_1 > \\ THEN\ < ACTION\_2 > \\ \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots . \\ THEN\ < ACTION\_3 > \end{gathered}$$

Tab. 1. Truth table

A	B	A and B	A or B
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	1

Applying decision rules is a relatively simple way of representing the expertise of a decision support system. Decision-making rules are best suited for regular, repeated decisions. Decision-making rules can be implemented simply and straightforwardly in the form of binary commands. Simple binary planning rules are fast and powerful enough to store parts of relevant knowledge. Planning rules are easy to evaluate and understand for planners and others. Feedback for rule changes can be implemented relatively quickly. The simulation model can serve as a measure when changing or evaluating planning rules.

Computer simulation provides a mechanism by which the essence of a real manufacturing system, such as AMS, can be captured in the form of a detailed model that can be run, tested, and analyzed in many different ways. In particular, a computer model can be used to help design and plan AMS, and ultimately can also be used to model control logic and complex decision tasks [2].

One other technique that has proven useful in analyzing manufacturing systems is artificial intelligence (AI). Simulation and AI are complementary methods and can therefore be used together to produce cohesive systems in which many aspects of modern manufacturing plants can be designed, planned or tested. The main driver in today's AI-based manufacturing research is the use of Expert Systems (ES) or KBS. These systems consist of basic AI functions and are used to assist or provide expert advice on a wide range of issues such as adaptive production planning.

Combined simulation with an AI system is a way to identify problems with reactive AVS scheduling and provide advice or recommendations regarding AVS performance. Simulation and AI are in decision making, it seems natural that such an integrated system based on these methods is the basis of the environment for analyzing and developing the problem of reactive AVS planning. Up-to-date in line simulation and pre-production AI systems, you support an integrated intelligent environment that helps novice users build, test and analyze production system models are at the forefront of the search for the next generation of production simulation tools.

Multi-Agent systems (MAS) are typical KBS systems and agents can be seen as an extension of KBS. In the 1980s, researchers applied agent technology to tasks and considered it a promising paradigm for the production of the future [3].

In general, traditional system modeling and simulation create system models using a deductive reasoning method. This approach is a typical simulation method of modeling, or thus a top-down method, as well as the idea of reductionism.

Multi-agent system implements full order fulfillment and includes agents for order control, inventory management, production planning, capacity planning, material planning, production management (shop floor), supply chain network management and for production. Multi-agent system is a solution that integrates different technologies and techniques of artificial intelligence from different subfields (thinking, knowledge representation, machine learning, planning, coordination, communication, etc.) and that offer an efficient and more natural alternative to building intelligent systems, thus achieving a solution. the current state of complex problems in the real world that need to be solved (Oprea, M., 2004).

The agent's rules of conduct may differ in their sophistication, how much information is taken into account in the agent's decisions (this is called cognitive burden), the agent's internal models, including possible reactions or behavior of other agents, and the extent of his memory for past events. retains and uses in its decisions. Often, agents in a model lack adaptation because it is not a matter of creating the intended purpose model. For example, for an inventory chain model, it may not be necessary to model agent adaptation if the model aims to evaluate a set of specific inventory management rules [4].

3. CONCLUSION

From the analysis of existing knowledge and literature, it is possible to assess that the emphasis is on a rapid response to customer requirements. And it is no longer enough for customers to choose from the offered products, they want to configure the product themselves. The requirement is therefore for personalized products and therefore there is also a change in production systems adapted to these requirements.

An adaptive company is therefore in a much better position to take advantage of short opportunities and rapid changes in customer requirements. The current problem is that the factories are still quite static. The company implements a production line and optimizes it for one type of product. The three main goals of all production systems are price, product quality and the ability to respond to markets. For personalized products, it is very difficult to achieve the price of the product as for mass production due to the high cost of product variations. In order to speak of production as adaptive, several conditions must be met, and that is adaptability, which means the ability to act according to "if-then-else" rules, thinking that involves preparing new possible scenarios, and alternative "what if ..." strategies, and finally the expression of knowledge and the processing of that knowledge, which means focusing, identifying functions and organizing interconnected structures.

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Industry 4.0, employees, generations, production, professions, transformation

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PREDICTED VERSUS PERCEIVED IMPACT OF INDUSTRY 4.0 ON WORK

Abstract
Industry 4.0 is an unstoppable trend affecting the functioning of industrial companies in particular, the readiness of all companies for its implementation is important. Most of the incentives are aimed at simplifying technical implementation. An equally important area is the impact on the social environment, primarily the employees of industrial companies. Not only readiness in terms of the necessary competences, but also the willingness of employees will be crucial for the implementation of new technologies.

1. INTRODUCTION AND LITERATURE REVIEW

Industry 4.0 is a program initiated by the German government as a new way to automate manufacturing technologies, which entered the scene in 2011 [1]. The most important reason for this initiative is the expected increase in production efficiency, consequently also increasing productivity, the use of smart infrastructure, digitalization and other related benefits [2]. The benefits of implementing Industry 4.0 can be seen in many areas. The upcoming changes affect either moderately and gradually or more strongly the performance of most job positions. However, the development and implementation of technologies must be implemented with a careful and accurate assessment of the impact on the people working with the technology. Many people may approach new technologies with lack of trust. Different attitudes towards the introduction of new technologies can be influenced by a number of factors, whether it is a fear of losing a job, a fear of working with new equipment, or a lack of trust in new technologies. The age of the employee can also play a significant role. Younger employees

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(members of Generation Z) are generally more open to embracing new technologies than older ones, who may be suspicious of using tablets instead of paper-based workflows, for example, for fear of information loss and lack of clarity. The complete foundation of the field relies on smart devices being able to communicate with their environment. This means that employees assisting in production will be replaced by devices that can perform the required operations based on specific instructions. Therefore, the demand for manual workers will be reduced and replaced by robot coordinators. However, we can say with certainty that employees in various fields of industry will have to acquire entirely new skills. This may help to increase the need for new professions, but it will also force employees to move into other professions. In particular, professions characterised by simple operations, repetitive and routine work will be challenged to keep up with technological progress in industry. More development options will have to be established, but this will not solve the problem of the older generation of the workforce [3]. Which implies that employees will have to be skilled enough for organizations to adapt this technological concept [4]. Acquiring or developing a qualification is both a barrier and at the same time major challenge. When developing employees, it is important not to overlook workplace safety issues when employees interact with machines. This is highlighted by the impact of trust on the adoption of online technologies [5]. Industry 4.0 provides an opportunity for the creation of new jobs. But automation and digitalization are often associated with job cuts, which can lead to resistance to the introduction of technologies.

2. METHODOLOGY

Several studies have focused on the impact of Industry 4.0 on the future of work. As an example, study of the World Economic Forum, which is based on data mapping opportunities for job change presents scenarios for the future of work and the possible consequences. They emphasize the importance of anticipating for changes in work and the need to be prepared for reskilling and requalification. It represents an emphasis on providing employees with the opportunity to develop the skills and capabilities needed for the future workplace [6]. We see enhancing employability as an important initiative that is consistent with sustainable human resource management. In the research presented here, we have therefore focused on the question of how employees themselves perceive the vulnerability of their jobs to the impact of the introduction of Industry 4.0 initiatives. In order to collect data, a questionnaire for qualitative research was created. As most of the questions were open-ended and the closed questions required explanations of e.g. terms related to Industry 4.0. The qualitative research could only be carried out by trained interviewers who collected the responses. A total of 287 respondents took part in the research, from the position of employees of industrial companies.

3. RESULTS AND DISCUSSION

The respondents were employees, with a fairly balanced ratio of men and women, 136 men participated in the research, representing 47.4% of respondents. Women participated 151 women participated in the research, representing 52.6%. The research sample was also diversified in terms of age. In Table 1, the age representation of each generation can be seen. In the representation of employees on the basis of age, we are tending to divide on the basis of belonging to generational groups. We understand the term 'generation' as a group of people who share years of birth as well as experiences, as they have grown up and lived or are living through different periods of their lives under similar circumstances.

Tab. 1: Representation of each generation

Generation	Absolute abundance	Relative abundance [%]
Generation BB (1946-1960)	7	2.45
Generation X (1961-1980)	55	19.16
Generation Y (1981-1995)	150	52.26
Generation Z (1996-2010)	75	26.13
Total	287	100.00

The oldest generation in the labour market is Baby Boomers (BB), which is represented by people born between 1946-1960. The participation of this generation in the labour market is slowly declining. Generation X workers, born between 1961 and 1980, is one of the two most represented generations in the workforce. The other strongly represented generational group is Generation Y, born between 1981-1995. The youngest generation, represented by students, working students and people entering the workforce, is Generation Z, born 1996-2010.Respondents from a variety of industries participated in the survey. Employees from the automotive (22.65%) and engineering (12.19%) sectors were the most significant. There were followed by employees from manufacturing, logistics, electrical engineering, information technology, food processing, construction development and testing, metal fabrication and metallurgy etc. Table 2 shows the representation of employees on the basis of job type.

Tab. 2: Structure of respondents in terms of job positions

Type of job position	Absolute abundance	Relative abundance [%]
Production	28	9.8
Administrative	91	31.7
Specialist	47	16.4
Manager	39	13.6
Intern	62	21.6
Other	20	6.9
Total	287	100.00

Many companies have not yet adopted Industry 4.0 initiatives, while in others the introduction of new technologies is already making a noticeable impact on the daily work of employees. Table 3 shows how employees see the potential impact of Industry 4.0 on jobs.

Tab. 3. Perceived negative impact of Industry 4.0 on jobs

Type of job position	Absolute abundance	Relative abundance [%]
Production employees	200	69.5
Administrative employees	37	12.7
Specialist	19	6.4
Managerial positions	18	6.2

No position	13	5.2
Total	287	100.00

In the qualitative research, respondents also commented on the possible reasons why they perceived particular jobs to be under threat. The most frequently mentioned reasons were robotization and automation, redundancy due to overstaffing or the need for retraining; the other possibilities were that respondents do not know.

5. CONCLUSION

The adaptation of new technologies is accompanied by expectations, but also fears on the part of employees. It is the employees, as users of the technologies in question, who decide whether their implementation will be successful or not. An important challenge for employers is therefore not only to prepare employees for new technologies in terms of necessary skills and importance, but also to process perceived resistance to new approaches being introduced. Without constant progress, society could not exist. However, it is important to be prepared for the coming changes, to communicate their benefits and to reduce fears of possible negative consequences.

ACKNOWLEDGEMENTS

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Workplace air, wood dust, belt sander

Miroslav DADO[1], Anna LAMPEROVÁ[2]

MEASURING OF WOOD DUST EXTRACTION SYSTEM EFFICIENCY

Abstract
The use of an integrated extraction system is one of the basic technical measures to prevent the workplace air contamination by dust during sanding wood with a sander. The aim of this paper is to investigate effects of the sandpaper grade and wood species on effectiveness of integral dust extraction system during sanding wood with hand-held belt sander. The results show that, regardless of the wood species, the efficiency of the extraction system is higher for the inhalable fraction of wood dust compared to the respirable fraction.

1. INTRODUCTION

In the context of mechanical wood processing technologies, the process of sanding with a hand-held portable electric belt sander is one of the major sources of wood dust emissions. The hand-held electric belt sander must meet the basic safety requirements associated with the health risks caused by sanding dust emissions in accordance with the applicable legislative requirements. The use of an integrated extraction system is one of the basic technical measures to prevent the workplace air contamination by dust during sanding wood with a sander. The integrated extraction system consists of a fan, a system of dust transport channels and a dust collector. The individual design solutions differ from each other in different ways of transmitting the driving force from the motor to the fan, the arrangement and shape of the system of transport channels and the used dust collection system. The collection of dust from the sander outlet is usually carried out by a collection bag or by a cassette system. The collection bags differ from each other in the method of attachment to the grinder, the material used, the size, shape, handling options during sanding and the method of emptying. Cassette systems are made of transparent plastic with a perforated lid. They usually include a folded cellulose filter, which can be repeatedly cleaned by tapping or through blowing [1].

However, practical experience [2,3] as well as the results of the pilot study [4] indicate that, especially when sanding wood with a finer abrasive grain, the efficiency of the integrated extraction system is often insufficient. The aim of this paper is to investigate effects of the sandpaper grade and wood species on effectiveness of integral dust extraction system during sanding wood with hand-held belt sander.

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2. MATERIALS AND METHODS

The evaluation of the efficiency of dust extraction system was based on a comparison of the of the wood dust mass concentration values in the operator's breathing zone with and without the use of a dust collection cassette. Supplementary efficiency evaluation was based on ratio determination between the amount of wood dust collected in the cassette system and the total quantity of the wood dust generated during sanding. The experiment was designed as two-factor full factorial experiment involving two levels of wood species and three levels of sanding belt grain size with five repetitions in each combination. The setup of the laboratory experiment is shown in Fig. 1.

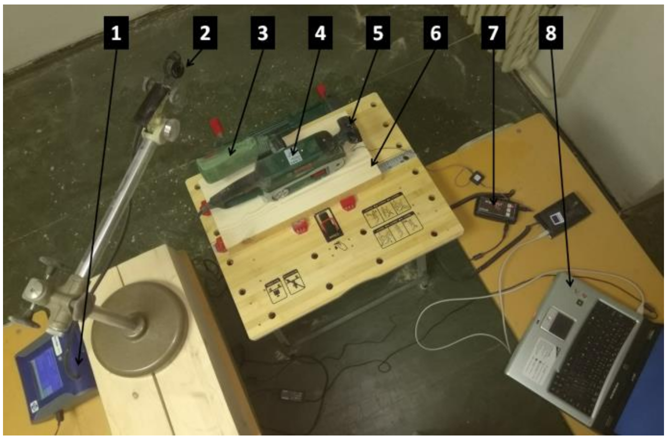

Fig.1. Layout of experimental setup: 1- aerosol monitor, 2-IOM sampler, 3-dust collection cassette, 4-belt sander, 5-pressure force sensor, 6-plank, 7-datalogger, 8-ErgoPak software

The input material for the production of the test specimens were cuts of beech (*Fagus sylvatica*) and spruce *(Picea abis)*. Test specimens were cut to the required dimension of 500 mm × 250 mm × 50 mm (length × width × thickness). Moisture content of the planks was 12%. Sanding was performed in longitudinal direction using a commercially available belt sander (Bosch, PBS 75 A). Abrasive belts with corundum grains bonded to a fabric backing using a synthetic resin binder (Klingspor, model LS 309 XH) with P40, P120 and P240 grit sizes were used for sanding. The sanding belt was replaced with a new one after sanding each test specimen. To ensure consistent sanding operation, monitoring the pressure force was performed by the load cell capacity sensor (Hoggan Scientific, ErgoPAK FSR). The pressure force 50N ± 5N was applied on the sanding surface. Inhalable and respirable wood dust mass concentrations were measured using a desktop aerosol monitor (TSI Inc., DustTrak DRX 8355). Each sampling event lasted 3 minutes. The weight of the test specimens was determined using an analytical balance (Sartorius AG, model BP 3100 P). The dust collection cassette weight was determined using a laboratory balance (f. Axis, model AG 2000 C).

3. RESULTS

The results of the evaluation of the efficiency of the wood dust extraction system based on the personal exposure reduction index are shown in Fig. 2. The results of the evaluation confirm the assumption that personal exposure to wood dust can be significantly reduced by using a dust collection cassette. The results of the evaluation also show that, regardless of the type of wood, the efficiency of the extraction system is higher for the inhalable fraction of wood dust compared to the respirable fraction.

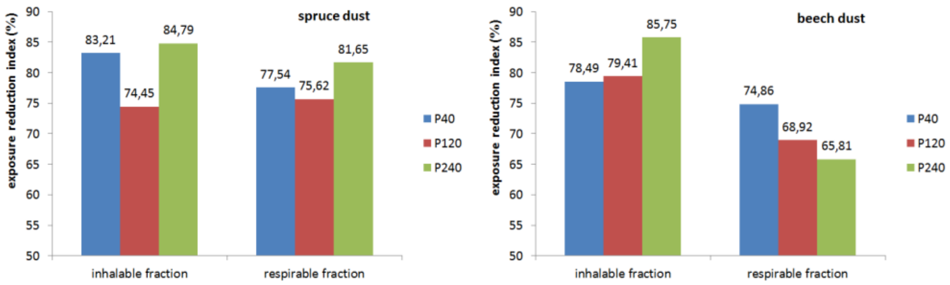

Fig.2. Efficiency of integrated extraction system based on personal exposure reduction index

The results of the evaluation of the efficiency of the wood dust extraction system based on ratio determination between the amount of wood dust collected in the cassette system and the total quantity of the wood dust generated during sanding are shown in Fig. 3. The largest amount of wood dust was trapped in the cassette system when sanding spruce wood using a sanding belt with a P40 grit size. On the contrary, the smallest amount of wood dust was captured in the cassette system during sanding beech wood with P240 grit size sanding belt.

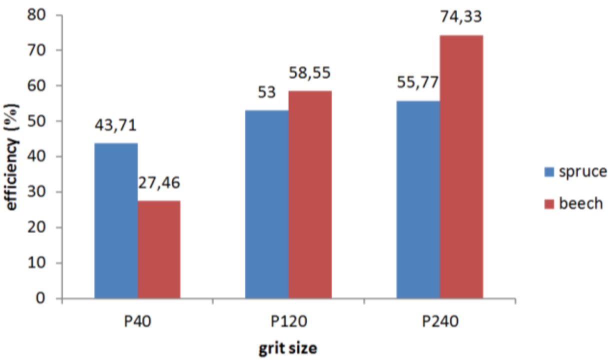

Fig.3. Efficiency of the integrated extraction system based on mass of trapped dust

4. DISCUSSION AND CONCLUSIONS

There are several approaches to verify the effectiveness of belt sander's integrated dust extraction systems. In this experimental study, two approaches were used: efficiency evaluation based on comparison of wood dust mass concentration values in the operator's breathing zone and efficiency evaluation based on determining the ratio between the amount of dust trapped in the cassette system and mass removal. Based on a reciprocal comparison of the mentioned evaluation approaches in relation to the achieved results, it is possible to declare their quasi-divergent character. Despite this, the achieved results are consistent with results reported by Thorp and Brown [5]. In their study, electric belt sander with cotton cloth filter bag was used to sand beech wood and they reported reduction in airborne dust concentrations ranging from 66 to 72%. In contrast, Douwes et al. [6] found that using a cassette system with a microfiltration system even increased dust emissions by 73%. In any case, it should be noted that in the above-mentioned laboratory experiment, an orbital sander with a P180 abrasive grit size was used to sand the MDF boards. Based on the results obtained and our own empirical experience during the experiment, it should be emphasized that despite the significant reduction of personal exposure to wood dust, the use of an integrated extraction system does not completely eliminate exposure to wood dust and the use of personal protective equipment thus remains a necessity during sanding wood with a hand-held electric belt sander.

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Designing, 3D modelling, bag breaker, recycling, waste segregation, Inventor

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DESIGNING DEDICATED BAG RIPPER FOR MUNICIPAL WASTE SEGREGATION

Abstract
The study presents the design of a bag breaker dedicated to a waste processing plant. The device is designed to break bags filled with waste in order to facilitate the process of waste segregation before they are recycled. The presented approach provides a comprehensive solution that can be approved for use because it meets the necessary safety requirements and those set by the customer factory. An additional advantage of the designed ripper is the possibility of mounting on the existing conveyor that transports waste to the sorter. This solution makes the device extremely economical in terms of the space occupied in the factory.

1. INTRODUCTION

Recycling is an extremely important strategy to mitigate the impact of human society on the environment [1]. Rational waste management allows to save natural resources, reduce the emission of harmful factors such as carbon dioxide, reduce the burden on the environment with solid and long-decomposing waste, as well as save energy and production costs [2]. Recycling has become very popular in recent years, there are more and more investors, factories that process waste are being built, and thus jobs are also created [3]. Unfortunately, despite its benefits, it is a complicated process, because so far no simple waste treatment system has been developed [4]. In addition, the situation is complicated by the fact that usually individual regions have different recycling rules [5].

Waste processing factories are specialized plants that receive, sort and treat waste in order to obtain reusable raw materials [6]. These types of bets can be divided into two groups - "clean" and "dirty". "Clean" factories are equipped with conveyors which transport waste to sorting devices. At the conveyors, there are usually workers who cut waste bags and select unsuitable for processing and oversized items (Fig. 1). Dirty plants separate recyclable waste from non-reusable waste which is then landfilled. Recycled materials do not differ in quality from new goods. They are a safe product that can be re-introduced to the market. In recycling processes, particular attention is paid to quality. Waste cannot be processed endlessly, as it loses its use value over time [7].

The first, very important step in waste processing is sorting it. Mixed waste is usually sent to the factory as people are much more likely to participate in recycling programs when waste is

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not sorted [8]. An additional advantage of this situation is that trucks transporting waste are able to take more waste than if they are sorted. So most of the time, sorting takes place in the processing center.

Fig. 1 Sorting of municipal waste [9]

Waste sorting plants can be more or less technically advanced. The sorting process is usually carried out with the use of a series of devices designed in such a way that it is possible to separate individual materials from the mixed heap. Separators are equipped with a magnet, screens, air and a number of sensors that identify various materials on the basis of their color, density or even conductivity [10]. Before sorting becomes possible, however, it is necessary to cut open all the bags with waste and remove elements that are too large and unsuitable for processing from the conveyor that transports them to the sorter. Most often it has to be dealt with by people who stand next to the conveyor belt and perform these activities manually. Such a solution means that several people cannot perform other activities in the factory, but have to deal with the preparation of waste delivered to the sorter.

2. DESIGN OF A DEVICE FOR BREAKING BAGS AND GRINDING LARGE WASTE

The design of the device for tearing bags and shredding large-size waste (Fig. 2) was commissioned by one of the companies dealing with collection, segregation and recycling of municipal waste. Before starting the model execution, it was necessary to define the limiting conditions as a consequence of:

- limited space in the sorting hall
- the necessity to implement a safety device that disables the machine, in the event of a possible fall of an employee on the conveyor belt,
- the need to obtain high strength of the shredder, with the lowest possible weight and dimensions, and thus - the lowest possible cost of the device while maintaining high quality of operation,
- possibility of quick and easy assembly and disassembly of the device.

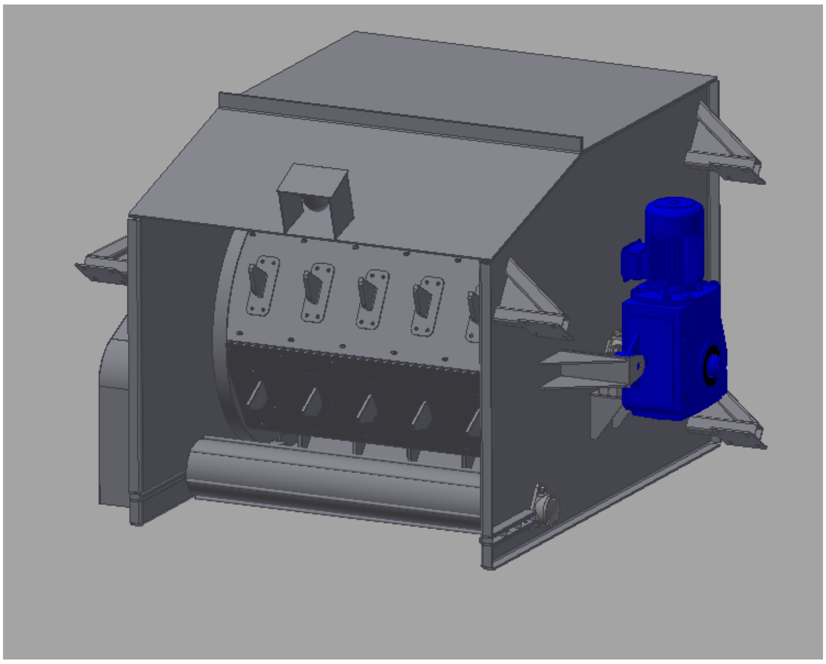

Fig. 2 Project of a bag ripper and large-size waste shredding (main view)

The most important problem was the limited amount of space that could be used for the installation of the designed device. The solution proposed in the developed project meant that no additional space was needed. The tear-off machine was integrated with the existing conveyor (bringing mixed waste to the sorter), and the only change that was needed in the conveyor was cutting out the attachments (preventing the waste from spilling from the conveyor belt) and setting the tear-off in this place, slightly above the conveyor belt itself. This solution made the ripper very versatile, as slight changes in the design (width changes) are enough to be able to build a device that will work on any other conveyor. This idea, however, had some shortcomings. It should also be noted that there is a possibility that an element, e.g. an elongated rod, after passing through the working space of the tearing machine, becomes jammed on its teeth and rotates with the drum of the device, causing damage to the conveyor belt. To prevent this, a cover plate is placed under the ripper drum (highlighted in blue in fig. 3) and a smaller drum is introduced, which throws the waste into the working space of the device.
The second very important issue was securing the machine in the event that an employee ran into the conveyor belt. For this purpose, the designers used a vision camera aimed at the working space of the conveyor, which has a temperature sensor and the ability to turn off the conveyor's operation when a person is detected on the belt.
In addition to the teeth on the drum, the machine also has a series of teeth above the drum. The teeth of the drum are responsible for introducing waste into the working space of the tear-off machine, and the upper teeth enable the process of tearing the bags with waste and destroying large elements. The upper blades have a slight upward movement to prevent excessive damage.

Both drums are provided with discharge channels (Fig. 4), which allow them to be removed from the device without the need to disassemble the main sheets. The drums are connected to each other by means of a chain transmission (simplified view in Fig. 3 - the presented wheels correspond to the actual dimensions of the wheels used).

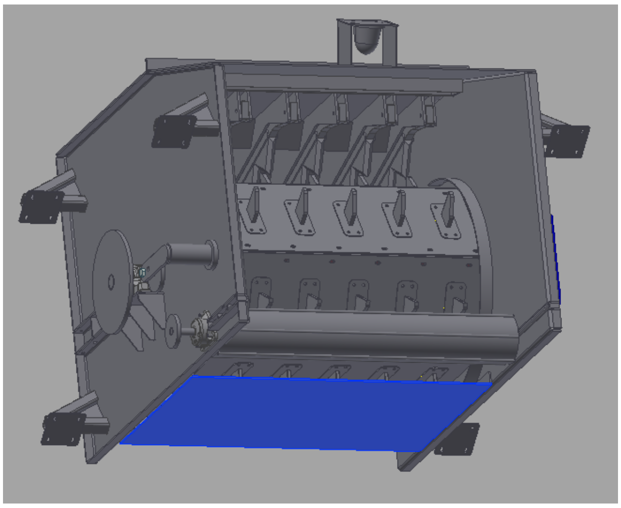

Fig. 3 A bag tear and large-size waste shredding machine (bottom view with a hidden gear cover)

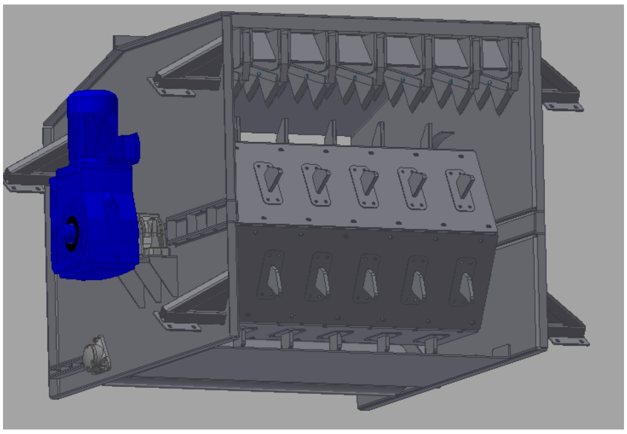

Fig. 4 A bag opener and large-size waste shredding (bottom view with a hidden gear cover)

Fig. 4 shows the construction of the drum. It is made of a shaft, three identical sheets determining its dimensions and peripheral sheets used to assemble the units with blades. Nuts were welded to the sheets on the perimeter, so that it was possible to easily and quickly replace one damaged blade unit, without the need to replace the entire drum in the event of any damage.

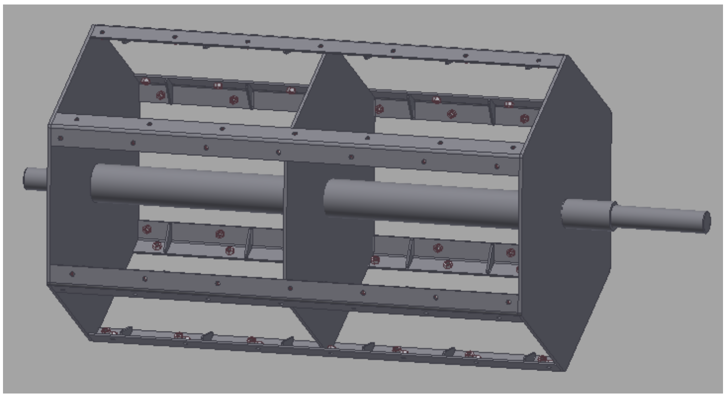

Fig. 5 View of the drum structure

3. COST OF EXECUTION OF THE DESIGNED DEVICE

As part of the construction works, in addition to the model, the cost estimate of the designed device was also prepared (Tab. 1).

Tab. 1. General costs estimation for the execution of the designed ripper

	Service	Cost
1	3D design with documentation	1 200 PLN
2	Total cost of steel and sections	19 000 PLN
3	Bearing housings from SKF company	3 000 PLN
4	Gear motor NORD SK9042	5 900 PLN
5	Vision camera	850 PLN
Total costs		**29 950 PLN**

The prepared cost estimate includes all the costs of making the ripper. Position no. 2 in the table (price of steel and sections) also includes the cost of their cutting and welding by the assembly company. The table does not include the costs of transport and assembly of the device on site, and all the rates given apply to the period from November 2021 to January 2022.

4. SUMMARY AND FINAL CONCLUSIONS

Recycling is a rapidly growing strategy to reduce the negative impact of waste on the environment. The benefits it brings have resulted in the creation of many recycling factories in recent years, and thus - the search for newer and newer solutions to facilitate work in waste processing. One of the main problems faced in this work was that a lot of waste was sent to the factories in sacks. Such a common regularity was a stimulus for the creation of devices that could help people to cut open the bags, which is undoubtedly a very monotonous activity.

The tearing machine for bags with waste and large-size elements, which is the subject of this article, differs significantly from the existing devices of this type. Most of the known solutions that perform the same function are much larger, bulky, self-contained devices that require continual handling in delivering the waste onto the conveyor and picking it up after it has passed through the working space of the ripper. The authors of the project presented in this paper proposed an innovative approach and achieved a very satisfactory economic result. The device they designed is much smaller than the existing tear-off machines, and integrating it with the conveyor means that it requires practically no free space. At the same time, it does not differ from other devices in terms of work efficiency and does not require human operation. An additional advantage of this innovative solution is the low cost of execution, which currently fluctuates around 30 000 PLN.

Installing the ripper presented in this study will reduce the number of people operating the conveyor that delivers waste to the sorter from 4 to 2 (possibly even 1). The only job that a human being will have to do is remove unrecoverable parts from the conveyor belt.

A number of advantages of the device discussed in this article make it competitive with other openers and willingly used by owners of recycling plants.

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Lean production, Industry 4.0, Big data, Just in time, Kanban, Jidoka, Kaizen, TPM

Samuel JANÍK[1], Miroslava MĹKVA[2], Lucia GRAJZOVÁ[3], Peter SZABÓ[4]

USE OF AHP METHOD IN INTEGRATION OF SELECTED LEAN MANUFACTURING METHODS WITH INDUSTRY 4.0 - BIG DATA

Abstract

The integration of lean manufacturing and Industry 4.0 can help organizations identify ways to link traditional lean management tools with Industry 4.0 digital technologies. By integrating these two philosophies, it is possible to achieve strategic goals, reduce costs and increase competitiveness. The main objective of this paper is to identify the optimal lean manufacturing method to integrate with Industry 4.0 technology - Big Data.

1. INTRODUCTION

With today's constantly advancing digitalization of industry in the context of Industry 4.0 and the associated change in production processes, it is important to explore ways to produce more efficiently than the competition. The Industry 4.0 revolution offers new opportunities, but it also brings potential threats to current methodological practices. Lean manufacturing methods are a widely accepted methodology with a focus on value-added activities – when applied correctly, they can increase productivity, flexibility and reduce production costs. By effectively linking Industry 4.0 and lean manufacturing methods, it is possible to take the current paradigm to the next level.

2. THEORETICAL REVIEW

2.1 Exact methods in decision making

Decision making is associated with people's mindsets and their expected outcomes [1]. Decision making can be defined as a non-random choice (selection) of one of a set of possible

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solutions (options) based on a well-thought-out reason in terms of meeting a set goal. In terms of the degree to which scientific methods are used in the formulation of a decision, decision-making methods can be divided into three groups [2]:

- Empirical decision-making – based on the decision-maker's knowledge of reality and his or her own experience.
- Exact decision-making – is based only on logical judgment and practical experience, the essence is the algorithmization of the decision-making process, the possibility of its model representation and mathematical solution.
- Heuristic – the intersection of empirical and exact approach to decision making.

Among the most effective methods of decision making we can include exact methods [3]. Exact methods, i.e. methods designed to solve decision problems that are recurrent and where the relationships between elements are expressed quantitatively, include, [2]: methods of mathematical statistics, mathematical analysis and linear algebra, methods of operational analysis and methods of multi-criteria decision making. Solving just a multi-criteria decision problem is a procedure that leads to the determination of the "optimal" state of the system with respect to more than one criterion under consideration [4]. There are a number of different methods that basically work on the same principle. The only differences between the different methods are in how the weighting of the individual criteria is determined and how the degree to which the different solution options meet the chosen criteria is numerically assessed [5].

2.2 Industry 4.0 and Lean Production Principles

In recent years, a new paradigm of Industry 4.0 (the fourth industrial revolution) has been defined with the potential to take manufacturing processes to the next level [6]. Businesses tend to make more use of intelligent systems to reap the benefits that the Fourth Industrial Revolution brings [7]. Industry 4.0 can be defined as an industrial vision that enables the real-time interconnection of people, things and machines, thus ensuring the exchange of necessary information between them, which poses new challenges for organizations in finding ways to apply Industry 4.0 and lean manufacturing concepts at the same time [8]. The question then arises whether the principles of lean manufacturing management can also be applied in the context of Industry 4.0 [9]. To realise the full potential of Industry 4.0, companies need to understand the new technologies and their opportunities - to do this, it is essential that different systems are fully integrated with each other [8Designing the integration of lean manufacturing and Industry 4.0 can help organizations identify ways to link classic lean management tools such as Just in Time, Kanban, Jidoka, Kaizen, and TPM with the digital technologies of the fourth industrial revolution. Such an integration design would align the lean manufacturing system with the new technological trends of Industry 4.0, making it to effectively meet the stated goals of the organizations. By integrating these two philosophies in manufacturing companies in particular, it will be possible to achieve strategic objectives, reduce costs and increase competitiveness [9].

3. DATA AND METHODOLOGY

The AHP method is specifically designed to deal with complex situations where the most optimal decision needs to be reached. The basis of this method is the division of a multi-criteria problem into smaller parts and the subsequent creation of a hierarchical model. Multi-criteria decision making is concerned with the analysis of decision problems in which there are several solution alternatives and several optimization (decision) criteria need to be considered. After the model is constructed, the assessor derives a square matrix of pairwise comparisons for each parent element at each level. The values given in the matrix will represent the preferences of that assessor for that pairwise comparison. The whole process of applying the AHP is completed by performing a final synthesis to derive the resulting preferences of the variants to the goal [10]. The AHP hierarchy generally has three levels: goal, criteria and variant [10].
Based on the relationships identified by reviewing the available literature [9] [11] [12] [13] [14] [15] were identified potential synergies between selected lean manufacturing methods and Industry 4.0 technologies, specifically Big Data. This is as follows:

- Big Data – the concept of Big Data provides analytics to enable insight into the customer's in-process experience, their requirements and the quality of the products themselves. Big Data is undoubtedly becoming an important trend in process optimization [16] [17].
- Just in Time – relies on the elimination of all non-value-added activities and wastage within the supply chain. The ideal state of JIT is production without inventory [18].
- Kanban – the aim is to maintain a smooth material flow with predefined stock levels to ensure an uninterrupted supply of materials. Industry 4.0 technologies have the potential to streamline this process [12].
- Kaizen – refers to activities that continuously improve all processes across the organization by involving all employees [19].
- TPM – is an innovative approach to maintenance that optimizes equipment efficiency, eliminates breakdowns and supports autonomous maintenance [20].
- Jidoka – is a principle helping to improve the quality of the production process, based on real-time quality control of the production process, and immediate stopping when poor quality is found [21].

Based on the results of the authors' research [9] [12] [15] a matrix (Tab. 1) was created that defines selected lean manufacturing methods that have the greatest potential for integration with Industry 4.0 - Big Data. This matrix is the basis for determining the variants for the AHP method.

Tab. 1: Combination of lean manufacturing methods and Industry 4.0 technology - Big Data (own processing, 2022)

	BIG DATA
JIT	**X**
KANBAN	**X**
KAIZEN	**X**
TPM	**x**
JIDOKA	**x**

4. RESULTS AND DISCUSSION

The main objective of the paper is to identify the optimal lean manufacturing method to integrate with Industry 4.0 technology - Big Data. The selection of the optimal method will be evaluated from a general perspective, by penetrating the application possibilities of medium and large industrial enterprises on the basis of established criteria. Based on the literature studied, objective reality, intuition and experience of the authors, the following are the decision criteria for selecting the optimal method:

1. Synergy benefits – the intersection of the benefits that industrial enterprises will gain by integrating lean manufacturing methods with Big Data technology.
2. Technical complexity of implementation – the difficulty of ensuring a smooth synergy of the two paradigms, lower technical complexity of implementation reduces the risk of unwanted errors.
3. Financial complexity of implementation – reflecting the amount of investment required, while the lower capital required does not expose the organisation to as much liquidity risk.
4. People skills – soft and hard skills required to ensure the functionality of the selected synergy. Lower skill intensity does not put pressure on the company to retrain or select new employees.
5. The implementation time is expressed as the time required for the overall integration of the selected synergy. Lower time intensity does not tie up the capital of the organization.

Based on Table 1, the variants are the selected lean manufacturing methods:

- JIT
- KANBAN
- KAIZEN
- TPM
- JIDOKA

The objective, criteria and individual options were entered into Expert Choice for evaluation. Pairwise comparisons of the individual criteria with respect to the stated objective were then continued. Pairwise comparisons were based on personal experience, intuition and information obtained from the literature reviewed. Expert Choice software was then used and values were entered numerically. The order of importance of each criterion from most to least important in selecting the optimal lean manufacturing method to integrate with Industry 4.0 - Big Data technology is as follows:

1. Benefits of synergy.
2. Financial complexity of implementation.
3. Technical difficulty of implementation.
4. Time complexity of implementation.
5. Qualification demand on people.

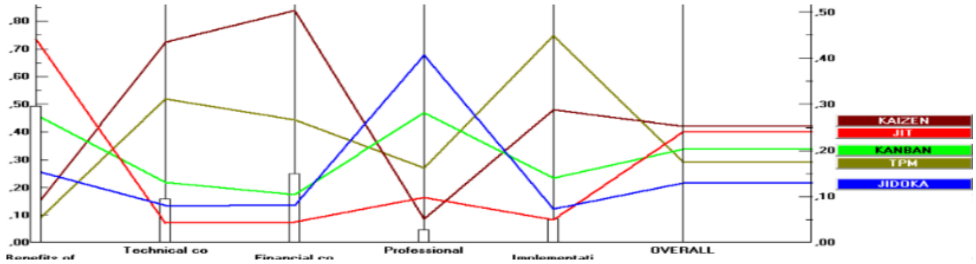

Fig. 1: Expert Choice user interface with Performance sensitivity diagram (Source: own processing of AHP Method in Expert Choice Software, 2022)

Fig. 1 shows the evolution and resulting order of the decision process. Based on the results of the AHP method, "Kaizen" can be considered as an optimal lean manufacturing method that can be integrated with Industry 4.0 technology. In most of the pairwise comparisons, the Kaizen method was the most suitable method compared to any other lean manufacturing method. Examples that appear to be weaker for integration in terms of the criteria are Skill intensity on people and Benefits of synergy.

5. CONCLUSION

Companies around the world are constantly facing new challenges as a result of economic crises, which are driving them to seek new business opportunities and strategies to profit and consolidate their market position. Moreover, the environment in which organisations are embedded is highly dynamic, forcing them to constantly adapt to new practices and market needs to ensure the continued sustainability of the business [6].

By using the AHP method through Expert Choice software, we were able to meet the stated objective of the paper. Based on the outputs of the software, we identified the optimal lean manufacturing method to integrate with Industry 4.0 – Big Data. The lean manufacturing method - Kaizen is able to synergize with Industry 4.0 – Big Data technology to reduce costs, increase competitiveness and ensure increased business sustainability.

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Simulation, optimization, digital enterprise, bottleneck

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ELIMINATION OF BOTTLENECKS ON THE PRODUCTION LINE BY IMPLEMENTING FLEXSIM SIMULATION SOFTWARE

Abstract

The current trend in production management and planning is the use of computer simulations. Under the term computer simulation, we can also imagine a digital enterprise as a tool of Industry 4.0. The article points to the possibility of using computer simulation. The main goal of this article was to streamline the bottleneck of the production line. It was also important to create an analysis of the staff in front of the bottleneck. Based on the analysis of the production line, it was later possible to create a simulation model in FlexSim software. The functional simulation model and the overall results of the model were subsequently verified with the real results of the production line. Later, it was possible to implement proposals for a production line solution to streamline the bottleneck.

1. INTRODUCTION

The digital enterprise is one of the modern tools, thanks to which it is possible to obtain a digital model of various elements of the enterprise, such as technology, people, production, production lines and the like. Subsequently, it is possible to implement various changes in the digital model and see their impact before they are implemented. Which can ultimately save high costs, which is the goal of any business.¶ It is possible to use a large number of simulation software to digitize production processes, detect bottlenecks that arise in them and their subsequent optimization. In this case, the FlexSim software module was used.

2. PRODUCT AND ITS PRODUCTION

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The main product discussed in the article is the compressor (Fig. 1), its components and their production and assembly. Manufactured compressors are used not only in refrigerators but also in freezers, industrial machines, refrigerated counters, beverage coolers, refrigerated display cases and the like. Currently, the greatest demand is for EM compressors for domestic refrigeration. The compressor is the heart of the refrigeration system. It deals with the suction and compression of the coolant, which allows it to circulate throughout the unit (e.g. in the refrigerator).
One of the main parts of such a compressor is the stator (Fig. 2), which we will analyze and optimize its production.

Fig. 1 Compressor and its stator

2.1. Stator production line layout

The production line consists of manual positions, semi-automatic and automatic machines. The material flow on the Statory EM production line is linked by conveyors. Belt conveyors are used. Their speed is approximately 0.2 m / s. Fig. 2 shows the layout of the production line, where the beginning of the production process is on the left, the figure also shows the layout of the production line workers. The production line also includes indirect workers such as an adjuster, tool technician, maintenance worker or quality manager. These workers may be responsible for several production lines.

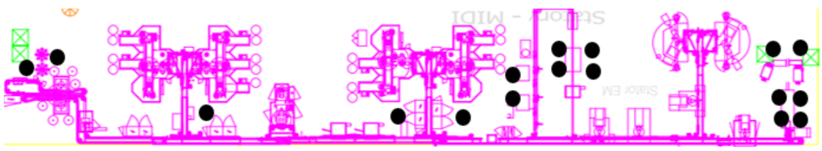

Fig. 2 Stator production line layout

The production process of the stator assembly to its final form consists of the following operations Tab. 1.

Tab. 1 The production process of the stator

Operation name	Procedure time in sec.
Production line input	-
Loading slats on the turntable (Queue)	1,99
Preparation of stator bundles	3,97
Stator bale height check	5,00
Stator harness isolation	15.32
Handling robot	7,36
Winding of working winding	16,13
Modification of working winding terminals	5,63
Pressing of working winding	8,16
Insertion of H-insulation	6,55
Start-up winding winding	15,11
Start-up winding pressing	7,28
Wire modification	2,59
Crimping	13,58
Insulation installation	5,05
Insulation shrinkage in a resistance furnace	4,3
Correct establishment of contacts	7,58
Winding opening using a press	7,18
Stator forming before sewing	18,8
Sewing of windings	24,00
Final press forming	7,49
Manipulator	6,56
Visual control	5,93
Stater tester	12,3

2.2. Analysis of operators' activities in front of a bottleneck

Based on the analysis of the entire production process of stator bundles, it was found that the bottleneck on this line is the position: Pressing of the working winding. In the following sections, we will discuss a proposal to improve this process. In front of the bottleneck are operators 501773, 501774 and 501775. In the case of operator 501774, the activities do not change and still perform a monotonous activity, so the analysis of its activities was not necessary.

2.2.1. Analysis of operator's activities - 501775

Operation / task description:
1. Gently open the upper part of the winding with your hands,
2. Adjust the lead wires,
3. Visually inspect the windings and insulation,
4. Press the button to send stators to another workplace,
5. The cycle time of the operator is 5.63 s / piece.

Expected results:

Properly wound, inserted and stripped stator main winding, without damaging the winding, insulators or stator plates.
Operations related to the operation of VA704, VA705 devices:

- In addition to the activities already mentioned, the operator has the task of adding material to the equipment and in case of model change, replacing the wire, pulling the wire that was intended for the previous model in the winding device, loading the new model into the winding equipment and printer
- Based on the measurement of the activities of the given operator, it was found that the average duration of the wire exchange operation, the measurement of the winding resistance and the subsequent start-up of the winding device lasts on average 4:58 min.
- The operator also has the task of changing the tape on the VA705 and VA704. Average duration of tape change operation and subsequent tape measurement = 2:39 min.

2.2.2. Analysis of operator 's activities - 501773

Operation / task description:

1. Select slats from the pallet, load and fill the turntable with them,
2. Remove all damaged slats and align the stator harness,
3. It is also necessary to separate about half the volume of the slats, then turn the rotary table 180 0, return them,
4. Using the adjusting tool, it is then necessary to separate the total prescribed number of blades of the stator bundle, retraction devices
5. The cycle time of the operator is 1,993 s / piece.

Expected results:
Stripped bundle of stator blades in the total prescribed number, but no damage to the stator blades can occur. The insulators must not be damaged and must be in the correct position. The stator lamellas must have a continuous surface layer and cannot be oxidized.
Operations related to the operation of VA701, 702 equipment:

- addition to the activities in point 1, the operator has the task of adding insulating tapes to the VA701 and 702. After replacing the tapes, the operator must then use a caliper to check the correctness of the size of the cut piece of tape. There are 3 tapes on each production facility.
- The average duration of the insulation tape replacement operation and subsequent tape measurement = 8:22 min.

Based on the available information resulting from the analyzes of the production process, a simulation model was created (Fig. 3).

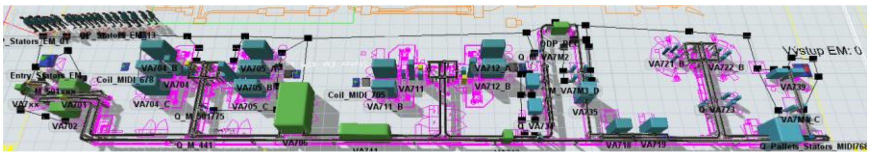

Fig. 3 Complete simulation model of the stator production line

3. PROPOSAL TO IMPROVE THE PRODUCTION PROCESS USING SIMULATION – ASSIGNING A NEW OPERATOR

Due to the high weight load of operators 1 and 2, operator 18 will rotate operators 1 and 2 and will also perform bottleneck-limiting activities. At the time when operators 1 and 2 add material to the isolation devices, operator 4 will load the slats on the turntable and create stator bales, thus reducing the weight load of operators 1 and 2. It is also necessary for operators 1, 2 and 18 to be qualified for all the activities it will carry out.
Based on the resulting report (Fig. 4), it is possible to see that the utilization of individual operators is more even. Despite the fact that operator 3 is occupied at 81.55%, it should be noted that the given operator has almost no weight load. The bottleneck utilization increased from 81.72% to 98.41%.

Fig. 4 Comparison of reports from the standard model and after the implementation of the design

4. CONCLUSION

Based on the model reports, which show the percentage expression of the utilization of individual operators, equipment, as well as the total output of the production line, it was subsequently possible to verify the results, with the results of the real production line. Given the results of the model, we can say that they are almost identical to the results of a real production line. When designing new production line solutions, it is possible to consider the weight load when handling the loads of individual operators. The proposed solutions for streamlining the bottleneck were a form of reorganizing the responsibilities of individual employees in front of the bottleneck. Following the implementation of the proposals, the target was achieved as the use of bottlenecks increased from 81.72% to 98.41%.

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Digitization, SolidWorks, AutoCAD, NavisWorks, Twinmotion

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DIGITALIZATION OF 3D LABORATORY IN VIRTUAL REALITY

Abstract
This article deals with the processing of real components, their process of creation, and their introduction into the digital sphere. Digital design is an integral part of today's industry. The article describes the program that was used, its benefits, and the work in the program associated with the creation of digital components. The creation of a digital model was solved in 3 programs. The Twinmotion program was used for the dual presentation of laboratory spaces.

1. DIGITAL MODELING

Digital modeling and model creation itself is understood as a process that combines 3D modeling and computing-aided design (CAD) with additive manufacturing. The most well-known additive production elements include 3D printing.
The purpose of the digital modeling and creation process is to enable the creation of digital models, which can then be used to test the final design.
Digital modeling is associated with 3 concepts (Digitization, Digitalization, and Digital Transformation).
Digitization is associated with creating the digital form of physical objects. It is possible to use scanning technology to create a digital model, or it is possible to use 3D modeling to create an accurate model in digital form. Digitization is thus the conversion of an object that is not in digital form into a digital representation. Computers then use 3D models to modify properties.

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Digitization is associated with enabling or improving processes using digital technologies and digital information.
The digital transformation is a real transformation that is the next step after the digitization process.
The benefits of digitization include:

- providing an overview and information for the real-time decision-making process,
- increase efficiency and productivity,
- improving the customer experience,
- business model innovation.

Advantages of digitization:

- strengthening the customer experience,
- mobility,
- sustainability.

Fig.1. Digital Transformation Pyramid

1.1 Programs used to create the digital design of the laboratory

Four programs were used to create the digital image, namely SolidWorks, AutoCAD Architecture, Navisworks, and Twinmotion.
SolidWorks was used to create 3D models. SolidWorks is one of the most widely used software used by engineers and developers. 3D models transform ideas into reality with the possibility of simulating designed parts and assemblies. If necessary, the model can be modified. The program allows you to instantly simulate design aspects in 3D and make the necessary adjustments immediately.
AutoCAD Architecture provides the tools you need to complete and scale faster. AutoCAD Architecture provides a library of more than 8,500 components, automatic generation of floor plans, views, sections, and ceiling partitions, and easy placement of shadows, doors, and windows with the ability to resize to the desired value.

In Navisworks, it is possible to visualize and unify design and construction data within a single model, and to identify and resolve collision and interference issues while still being built, saving time when remodeling.
The last program used in the digitization process is the Twinmotion program. The program offers real-time rendering to enhance presentations. The transition from interactive presentations to virtual reality presentations allows immersion in design.

2. CREATION OF DIGITAL LABORATORY COMPONENTS

We chose a laboratory for logistics processes to create the visualization. The laboratory itself is in the creation stage. At this time, the laboratory is already equipped with RTLS antennas, which are used to monitor the movement of material using tags.
The first step to successful digitization, which most represents the real form of the laboratory, which is part of our department, was the creation of 3D models of furniture and laboratory equipment. All models were created in SolidWorks. Thanks to the technical documentation of all parts, we were able to accurately draw the necessary parts. In SolidWorks, you can also combine parts into functional units. This is a huge advantage when the whole model cannot be drawn as one part but contains several components. Such an example is the stands shown in Figure 2. We also received a technical drawing of the entire assembly from the supplier. In the future, these stands will contain additional components for monitoring logistics processes and training students in virtual reality but also in the real presence of students.

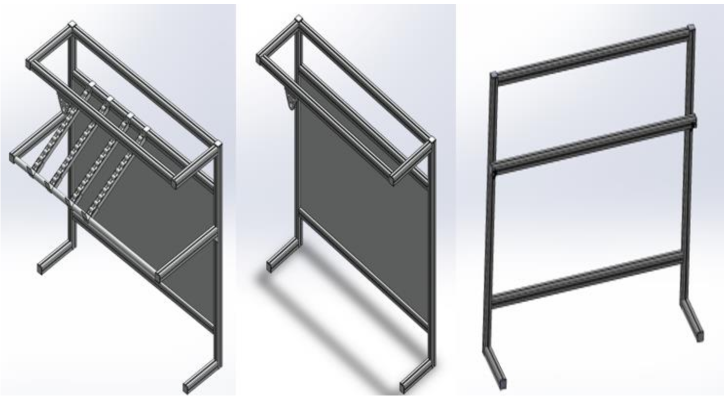

Fig.2. Digital models of laboratory stands

The next step was to create 3D models of furniture that is in the laboratory. Without this, the model would not be complete and the visualization would not have much informative value. SolidWorks was used again when creating. The program offers many benefits and was therefore chosen as the best option. Its simple environment is clear to the user, and the creation of three simple components does not require several hours of experience with the program. Objects such as the teacher's desk and the student's desk contained several components, so it was necessary to draw them as individual parts and then combine them into a set.

Fig.3. Laboratory furniture

3. CREATION OF THE DIGITAL FORM LABORATORY

If the process of creating 3D models is completed, it is possible to proceed to the next step, namely the creation of laboratory premises. We used AutoCAD Architecture for the creation. In the program, it is easy to pull out walls, enter parameters, and determine the position of doors and windows. It was necessary to measure the whole room to work with real data. Figure 4 shows the appearance of the laboratory exactly according to its dimensions. The program, as part of the AutoCAD suite of files, provides a link to another program that we used. This is a huge advantage as it is possible to return to Architecture, and make changes and these will be reflected in Navisworks.

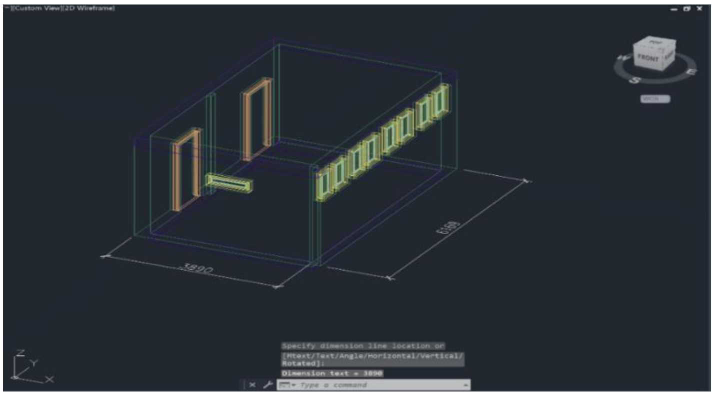

Fig.4. The appearance of the laboratory in the AutoCAD Architecture program

Navisworks reflects the 3D model of the lab, and you only need to insert 3D models of the parts we created in SolidWorks. However, it is necessary to export the models in the correct format, in the STEP format. When you insert a model into Navisworks, you can use the toolbar to rotate the rotated model along the axes and then place it exactly at the specified position in space.

However, when converting to STEP, the models lose their color. However, this is not a problem, as Navisworks offers a library of color combinations to achieve a realistic look. For comparison, Figure 5 shows the actual appearance of the laboratory and its appearance in the Navisworks program.

Fig.5. The appearance of the laboratory in the Navisworks program in comparison with the real form

The last step is to convert the model from Navisworks to Twinmotion. The supported file is. fbx. the problem is again the color of the model. After exporting the model from Navisworks to Twinmotion, it is necessary to reassign a color to the parts in Twinmotion. By assigning the color of walls, doors, and components, the final form is then ready for presentation in a virtual environment.

4. CONCLUSION

In conclusion, it is possible to note that the created model of the 3D laboratory is a good springboard for the presentation of the laboratory space in our department. However, this digital model is only the beginning and can only be used to present digitization. In the future, however, this laboratory will be equipped with additional parts that will help students and teachers to monitor logistics processes and training more. The digital image itself will be further improved. In the future, it will be possible to work in a virtual environment. The vision is to create, for example, a car transmission, and then students will be able to disassemble it, connect it and analyze its properties. The process of monitoring logistics processes in virtual reality will also be possible, as we still do not know how the situation with the pandemic will develop.

Creating a model is not a demanding activity, as work in the mentioned programs is taught in our department and program packages are available free of charge. However, during the creation, we also came across imperfections in the programs. In Navisworks, when you insert models, you can change position or rotate the model, but a number scale is not available to achieve the exact position of the model in space.

ACKNOWLEDGMENT

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Comparison, digital factory, digitalization, Industry 4.0, cloud computing

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COMPARISON OF THE CURRENT STATE OF IMPLEMENTATION OF INDUSTRY 4.0 IN ITALY AND SLOVAKIA AS PART OF THE TRANSFORMATION TO A DIGITAL FACTORY

Abstract

In order to achieve the potential benefits of digitalization, enterprises must be able to ensure that all their data is integrated and used in line with the implementation of Industry 4.0 technologies. The main aim of the paper is to compare the current stage of implementation of Industry 4.0 technologies in Slovakia and Italy in order to identify weaknesses in the digital transformation process of Slovakia.

1. INTRODUCTION

A fundamental assumption of Industry 4.0 is the integration of the Internet of Things (IoT) into the creation of added value in the industry. Industry 4.0 is defined by improving the interconnectivity of intelligent machines, physical objects, people, products, and processes across organization. This includes digital technologies such as Big Data (BDA), Virtual and Augmented Reality (AR and VR), Artificial Intelligence (AI), Collaborative Robotics, and Additive Manufacturing (AM), whose applications cover a wide range of possibilities and could enable industrial enterprises to perform more autonomous and efficient processes and tasks [1]. With the digital factory, people have access to accurate information in real-time. They can use this data in more intelligent ways to make business decisions, identify challenges before they happen, respond more flexibly, and be more resistant in an unpredictable, competitive world [4].

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Industry 4.0 has escalated global competition between developed and developing countries. Therefore, one strategy for governments is to develop programs that can radically change the global structures of major industries. Industrialization is essential for competitiveness. However, rich or developed countries look at industrialization from a different perspective. They implement it intelligently through public policies that encourage innovation. There is no set formula or single scheme for implementing Industry 4.0 technologies, enterprises generally adopt Industry 4.0 technologies which suit the requirements of their business. Global competitiveness is reaching unprecedented proportions and the industrial structure is changing rapidly due to investments by emerging economies in Europe, the US and China. The current competitive dilemma is not just about being a winner, but also about maintaining a leading position through a clear focus and coordinated effort to invest in Industry 4.0 technologies [2].

2. METHODOLOGY

More than 75% of the value of EU sold production was generated in 6 Member States: Germany (29% of the EU total), Italy (18%), France (12%), Spain (9%), Poland (5%) and the Netherlands (3%) [3].

The authors justify the choice of Italy for the comparison with statistics [3] according to which Italy is the second-largest manufacturing country in Europe and is mainly based on low- and medium-technology enterprises. In the survey that was used, the authors of the article focused on industrial enterprises in Italy [4]. The survey, which involved 100 managers representing industrial enterprises in Italy, found that Italy ranks high in many aspects of the Industry 4.0 digital revolution. The survey is based on a global survey of 19 leading Asian, European, and American countries. In February 2017 was launched The Industry 4.0 National plan, to increase investment in new technologies, research, and development in all enterprises and thus increase the competitiveness of Italian enterprises [5].

The research data concerning the Slovak Republic was collected through a questionnaire distributed to Slovak enterprises. The questionnaire was distributed online. A total of 138 respondents representing industrial enterprises participated in the questionnaire. The questionnaire focused on the stage of implementation of the 4th Industrial Revolution.

3. RESULS AND DISCUSSION

The following section is about the results. A survey in Italy [5] showed that 49% of industrial managers in Italy strongly agreed that the emergence of increasingly intelligent and autonomous technologies is the trend that will most affect their business in the coming years. Only 31% of respondents globally hold this view. This global survey showed that Italy is in a relatively advanced position when it comes to Industry 4.0 technologies as part of the transformation toward the Digital Factory.

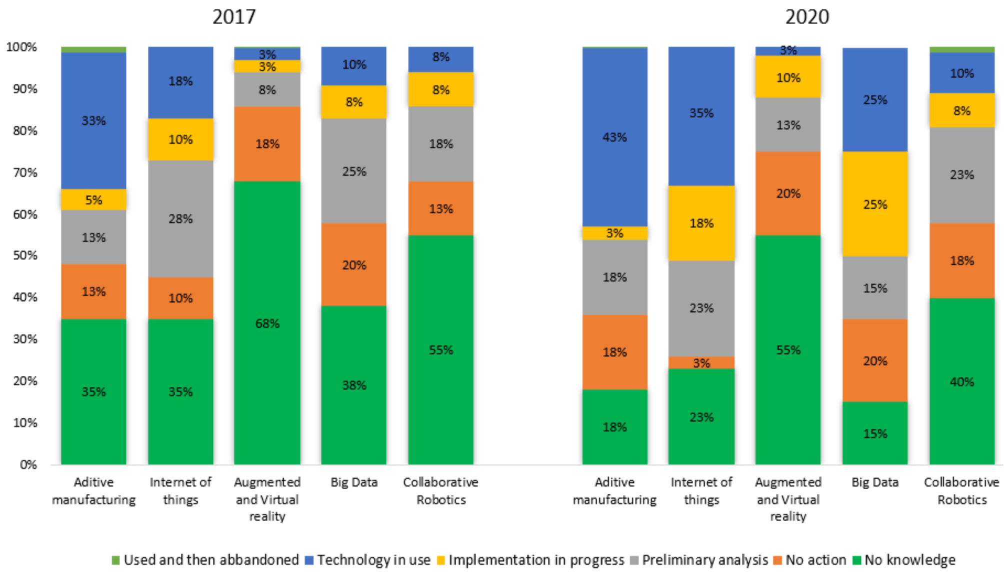

Fig. 1 Comparison of 2017 and 2020 levels of technology use in Italy
(Own processing based on [1])

Fig. 1 shows the level of use and adoption of Industry 4.0 technologies in Italian manufacturing enterprises in 2017 and 2020. The situation in 2020 compared to 2017 indicates a move in the awareness of Italian enterprises of the different Industry 4.0 technologies. In general, if enterprises want to become a competitive in the market they must adapt and respond to the new era that is Industry 4.0. Raising awareness is therefore the first step towards success. The decline in the option No knowledge in the figure is a positive result for Italian enterprises. It can be concluded that this decline occurred for all types of Industry 4.0 technologies surveyed. A significant decrease of enterprises having No knowledge about Industry 4.0 technologies is recorded in the BDA (Big Data) area - up to 23% in 3 years. The negative finding remains that 3-20% of enterprises (depending on the specific technology) have awareness of Industry 4.0 technologies, but have performed No Action about their planning or implementation in 2020. Progress has also been made in the case of conducting preliminary analyses of Industry 4.0 technologies. Also, more and more enterprises are adopting technology implementation solutions (e.g. for BDA, an increase of 17% compared to 2017). In addition, there has been an increase in the implementation or use of Industry 4.0 technologies compared to 2017. 28% of enterprises have implemented/used IoT (28), and in 2020 it was 53% (53). This represents an increase of 25%. It can be concluded that the evolution of the adoption of the 4.0 paradigm is still ongoing, although some technologies are showing more significant trends than others0 [1].

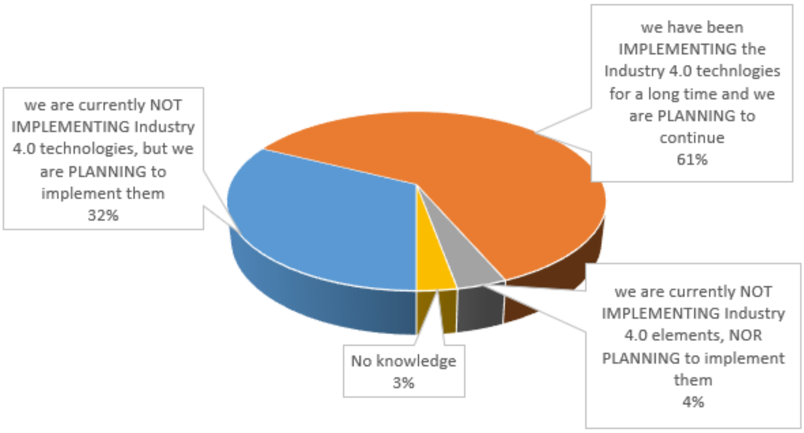

Fig. 2 The state of implementation of Industry 4.0 in Slovak enterprises (Own processing, 2022)

Fig. 2 shows the level of technology adoption brought by the Industry 4.0 revolution in Slovakia. 61% of enterprises (85) have already been implementing for a long time and plan to continue in this direction. 32% (45) of enterprises have currently made plans, but are not yet in the implementation process. 3% (4) of enterprises have no knowledge regarding the implementation of Industry 4.0 technologies. An equally interesting finding is the fact that in the current state 4% (5) of enterprises have no plans to implement new technologies in the future. Next, we will be looking at technologies that are already implemented in industrial enterprises in the following, we will consider only the cleaned research sample - 85 enterprises (61% of the original sample).

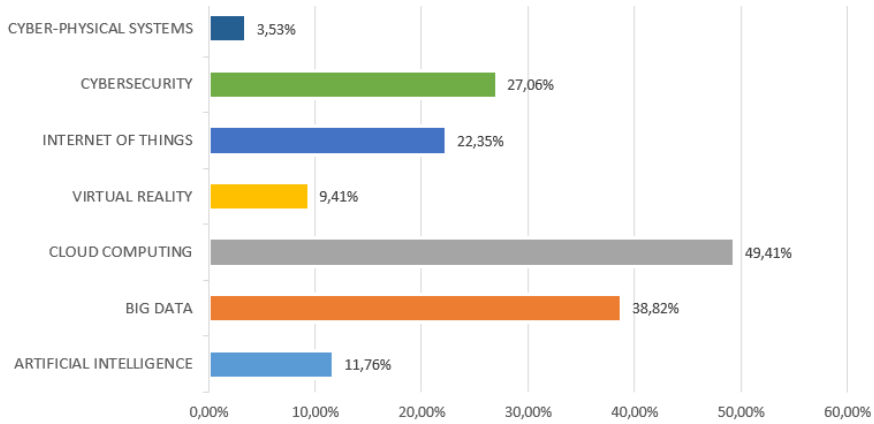

Fig. 3 Implementation level of selected Industry 4.0 technologies in Slovak enterprises (Own processing, 2022)

Fig. 3 shows specific technologies that have already been implemented in enterprises in Slovakia. Cloud Computing has a leading position in the implementation of Industry 4.0 technologies in Slovakia - 49.41% (42) of enterprises. Big Data is the second most commonly implemented technology, representing 38.82% of enterprises (33) compared to Italy, which has implemented Big Data in 50% of enterprises (50). 43% of Italian enterprises (43) have implemented the Internet of Things, while in Slovakia it is 22.35% (19). The authors conclude that Italy's policy contributes to improving the conditions for the implementation of Industry 4.0 technologies.

As part of the Industry 4.0 National plan, the Italian government has presented a plan to invest €18 billion in 2017-2020. This initiative aimed to contribute to the strengthening and development of digital innovation centers, but also of skills by encouraging Industry 4.0 training programs, and strengthening qualification training, and competence centers. The aim was to train an additional 200,000 university students, 20,000 technical institute students, managers, and 1,400 Ph.D. candidates, all with a specific focus on Industry 4.0 areas [6].

Within the framework of Industry 4.0 in Slovakia, the so-called Digital Transformation Strategy of Slovakia has been developed, which states that the movement towards industry oriented towards innovation and technology has a huge potential to become a real engine of economic growth in Slovakia. It is necessary for the Slovak economy to shift from classical industrial production to a digital level of the economy. Efforts will be made to leverage the technological potential and increase private and public investment in progressive Industry 4.0 technologies such as AI, IoT, 5G, Big Data, etc. To achieve this priority, Slovakia needs to do the following steps [7]:

- create opportunities for the implementation of Industry 4.0 technologies and promote the benefits of their use;
- engage in Europe-wide tests and pilot projects and promote their scalability,
- prepare for the deployment of 5G and autonomous transport technology.

4. CONCLUSION

Within the overall share of countries with industry 4.0 initiatives, it is estimated that only 25% are moving forward. European countries are making relatively rapid progress in the implementation of Industry 4.0. This may be due to strong international cooperation (European Union) with targeted Industry 4.0 policies. This is confirmed by the fact that Europe has more economically and technologically advanced countries than other regions. The European region leads the world, as half of its countries have already implemented Industry 4.0 strategies. However, the Middle East and Africa are still at an early stage of implementation and only a few countries have developed Industry 4.0 initiatives [2].

Individual countries are moving at their own pace of implementation. This is due to the fact that launching Industry 4.0 initiatives and technological development requires huge funding and resources. For this reason, there is a very visible inequality between countries and regions, as developed countries are not constrained by finances, unlike developing countries [2]. The Italian government presented a specific plan and invested 18 billion between 2017 and 2020, which was reflected in the results. Although the Slovak government has drawn up a Digital Transformation Strategy, it is mainly focused on the public sector and industry is lagging behind. Based on a comparison of the state of implementation of Industry 4.0 technologies in the Slovak

Republic and Italy, the authors conclude that it is necessary for the Slovak Republic to make greater efforts to support the development of industry towards digitalization. By promoting a paradigm of thinking towards digital factory. At the same time, enterprises need to realize the importance of raising employee awareness and providing training so that they can contribute to digital transformation across all the value chain. As the COVID-19 pandemic has shown, stability is never guaranteed. However, the digital factory makes enterprises more agile and able to react to everything that is happening in the economy and the world.

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Executive Information System, business intelligence, data storage

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BUSINESS INTELLIGENCE - AN ANALYTICAL TOOL FOR INDUSTRIAL ENTERPRISE AND APPLICATIONS

Abstract

Business intelligence tools are increasingly used in companies and institutions around the world. They are specifically designed to support the needs of executives. It is the part that works with selected or modified data and which through these modifications becomes the carrier of complex information, characterizing the relevant processes in the company. It primarily serves to identify and locate certain phenomena in the company, in the next step then for their detailed analysis. The operation of business intelligence tools as an integration factor is also considered very important. The paper discusses the basic principles of operation of these applications.

1. INTRODUCTION

One of the shifts that have taken place in enterprise informatics over the last few years has been the shift of priorities to strategic management. It is essential for such an approach to have enough correct information. This offers us a system of tools, project solutions and organizational measures known as business intelligence (BI), enabling knowledge-based management of organizations. The extensive area of business intelligence consists of a number of separate components has its own architecture and methodology and is linked to operating systems by a number of links. In addition to traditional applications, the MIS concept also develops EIS (Executive Information Systems) and data mining tools. The infrastructure of the whole area is usually based on the concept of a data warehouse [1].

The existence of a data warehouse is a prerequisite for the functioning of BI tools. It is a comprehensive database optimized for querying and analyzing data, along with tools that allow questions, analysis, and quality presentation of outputs. In the data warehouse, data is integrated and stored, whether it is data from internal or external sources. The ultimate goal is to provide readable, organized, analyzable, and real-time information from a maximum

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of corporate databases and external sources, which are widely used in the management of a company or institution [2].

2. EXECUTIVE INFORMATION SYSTEM

The transfer of integrated information systems (ERP - e.g., BAAN or SAP R/3) to all processes in the organization together with the advent of communication technologies leads to a dramatic increase in the volume of data in these systems. Therefore, the need for effective management requires the monitoring of aggregate information, the volume of which is not so large, but it is data with a considerable degree of aggregation. The Executive Information System (EIS) fulfills this purpose. It is an effective connection of the data potential of the operational transaction system with the management mechanisms of the organization and the analytical needs of individual management components. They are designed to allow access to external data and also to be connected to the organization's information system [3].
EIS can transport significant volumes of primary data generated by the basic processes of a given company into logical structures that represent management and decision-making processes in a particular company. They are characterized by simple operation (often intuitive) and contain effective means for clear presentation of data [4].

2.1 Characteristics of EIS

EIS use the so-called OLAP (On-Line Analytical Processing) tools, providing a highly efficient multi-criteria analysis mechanism. About 18 rules were defined for their evaluation, of which the first 12 were defined by E.F.Codd.
Principal features [5]:

- Intuitive data manipulation from the user's point of view - graphical interface, zooming;
- Support for multi-user operation - parallel approaches, ensuring the integrity and security of operation;
- Multidimensional concept and data manipulation - realizes data storage in a combination of defined dimensions, allows different data views according to dimensions and can change them dynamically;
- Ability to retrieve data from heterogeneous data sources - OLAP tools must map data storage states, access them, and ensure appropriate conversions to their own database;
- Offer custom databases for OLAP and direct access to external data;
- Support of modern analytical approaches;
- Transparency and openness - the ability to integrate with other tools without compromising the user, the user can use the data from the database with the tools to which he is accustomed. Transparency of internal data organization;
- Client/server architecture.

Special features [5]:

- Non-standardized data processing - integration of OLAP machine and non-standardized source data;
- Efficient matrix processing - missing values must be ignored by OLAP parsers regardless of their source;

- Distinguishing missing values from zero values.

Reporting features [5]:

- Consistent output performance - performance should not be affected by the number of dimensions defined;
- Flexible output delivery - easy output adjustments, display and combination of outputs according to the user's immediate needs.

Dimension management [5]:

- Unlimited number of dimensions and aggregation levels - the number of dimensions for the model should not be limited;
- Unrestricted operations across dimensions - data operations between individual dimensions cannot be limited by the number of dimensions;
- Generic dimensionality - additionally supplied functions must be provided for any dimension.

Adherence to OLAP standards, together with an assessment of the ease of deployment and control of the system and the supplier's ability to prototype a future application over a sample of your actual data in a short time, are clear criteria for selecting a specific EIS.

2.2 Multidimensionality of EIS

A typical feature of EIS is multidimensionality, which allows you to quickly and easily create new views of data, put them into new contexts, search for patterns (trend characteristics), indicate deviations of key indicators from planned values, and work with history and anticipate future developments. EIS applications are based primarily on the use of so-called multidimensional data storage. The basis is a multidimensional table that allows you to quickly and flexibly change the individual dimensions, i.e. change the user's views on the modelled economic reality [5].

The view of the economy of any organization is multidimensional. For economic applications that can be developed over time, the number of three dimensions used in spreadsheets is insufficient. For small organizations, the manager does not lose global insight and can track details. For larger organizations, the information for the manager must be carefully prepared. The multidimensional form of information is then very practical, perhaps even necessary. Tasks of this nature are typical tasks in companies, state administration, banking, control authorities, etc. The advantage of EIS in solving these tasks lies in the ability to work very operatively in a superspace matrix with a significantly larger number of cells. Several dimensional data storage is mostly implemented on the basis of a metadata superstructure over relational tables. Metadata assigns rows and columns of relational databases to individual dimensions and cells in an n-dimensional table. The metadata also contains rules for aggregating data at each level defined by the dimension. This is the principle of OLAP data storage technology or online analytical data processing [6].

The response to the change in view definition is then almost immediate in tools using OLAP technology. The problem of expansion of multidimensional data manifests itself only in certain situations, such as excessive hierarchical complexity of dimensions, increasing number of dimensions and the related rarity of data, etc. The issue of multidimensional data administration is also closely related to the type of storage and further processing of this data.

3. DATA STORAGE

Data storage (DS) is long-term storage, where data collected by classical information systems are added in individual batches. In the data storage: query responses may not be immediate, some data redundancy is allowed, and data is never discarded from the data storage (aggregate aggregations of some data and backups to external media can be performed).

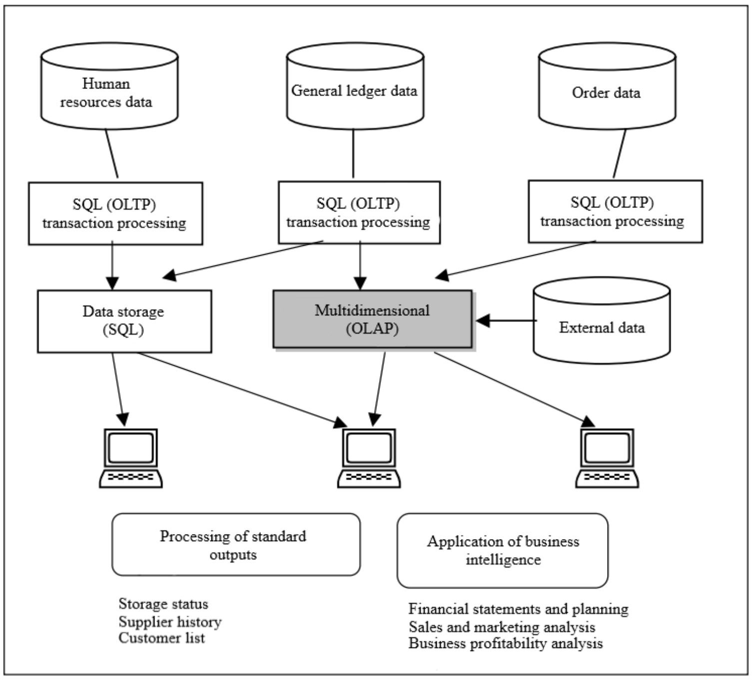

Fig.1 OLAP technology scheme - a comprehensive solution to support decision-making processes, also called business intelligence [7]

A characteristic feature of data storage is the diversity of sources. Resources for data warehouses are stored in completely different structures, and formats, have a different record philosophy, are stored on different media, etc. Data storage operate on the principle of three steps (ETL) [7]:

1. **Extraction** - the ability to take data from the widest possible range of data sources of various kinds. (One way to access this is through a standardized ODBC interface).
2. **Transformation** - a successive series of operations that prepare the extracted data for their own loading into the data warehouse. (Data is checked, supplemented, changed, converted to the same formats, and inconsistencies are removed).
3. **Load** - Data is loaded into the data warehouse's own physical space. (They are ready to extract or ask questions).

Two concepts have prevailed in the architecture of data warehouses - independent data marty (virtual data warehouses) and integrated data warehouses. Independent data marts are separate data repositories for individual applications or departments. Their disadvantage is possible inconsistencies between individual repositories and complicated loading processes. An integrated data warehouse is a central data warehouse where the requirement of consistency is absolutely essential (DS must provide a "single version of the truth"). This approach is currently prevalent [7].
The data storage is then used by business intelligence tools through a service called data mining. Data mining based on a certain assumption makes it possible to search for contexts and interrelationships in a large volume of data that were not known in advance. By being able to search for context data that was not known in advance, data mining differs from other methods of computer-generated data analysis. Data mining should always aim to solve a specific business problem or find a way to improve the process. The goal must be defined in advance and data should be prepared on its basis. Data mining is the search for hidden connections, the process of selecting, searching, and modeling large volumes of data. Used to reveal previously unknown relationships between data. Of course, data must be error-free, and complete, and formats from different systems must be unified. This ensures that they are stored in the data warehouse. The nature of data mining requires that data be kept up to date. The range of methods used to build a data mining model is very extensive. No model can be said to be universal and the best results are achieved by a combination of different approaches.

3.1 Integration Profile of Business Intelligence Tools

We consider the operation of business intelligence tools as an integration factor of the company's information system (IS) to be very important. They contribute to the integration of:

- management processes - data is available for all levels of management in almost the same time period,
- data integration - data storage creation and data mining implementation,
- information technology integration - at least through data they connect various information technologies and technology platforms used in the company, they become the engine of the connection of the company’s IS into a unified functioning unit,
- overall integration of the system - the BI application belongs to the strategic applications within the company. They transfer data between all levels of management in the company and thus represent an important factor for the integration of the entire IS of the company. During their development and implementation, the individual parts of the company's IS become aware of them and thus their final integration into a synergistically functioning unit - the company's integrated IS - takes place [8].

4. CONCLUSION

Our century can be characterized without exaggeration by an unprecedented information explosion. Managers and company executives are exposed to the greatest information pressure. The larger the company or is distributed in more places, the greater the pressure on the quality, relevance, reliability, and quantity of information provided. A capable and educated manager needs an adequate tool for a quality management superstructure of an information system for his important activity. It can be said that business intelligence tools integrate information and business strategy and help the company survive in the current turbulent environment.

ACKNOWLEDGEMENTS

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Material flow, software solution, optimalisation

Marián MATYS[1], Martin KRAJČOVIČ [2], Gabriela GABAJOVÁ[3], Beáta FURMANNOVÁ[4]

AN OVERVIEW OF THE SOFTWARE SOLUTIONS FOR MATERIAL FLOW OPTIMIZATION

Abstract
This article presents and briefly describes a few of the currently available software solutions for material flow optimization. Every solution has its strong and weak points that must be considered before the decision, either for companies or as a teaching tool in school. In total, four different solutions are presented.

1. INTRODUCTION

Every year, the technologies are more advanced and at a higher level than they were not so long ago. As time goes on, companies need to be able to keep up with these new technologies if they do not want to fall behind their competition. The calculations, methods, and procedures for optimization, which once all were solved on paper, have long been obsolete. In modern times, everything has a digital form and people are gradually replaced by machines to some extent [1]. The use of developed software solutions for material flow optimization can be used to save time and also reduce the probability of calculation errors.

2. THE SOFTWARE SOLUTIONS FOR MATERIAL FLOW OPTIMIZATION

In this paper, we will introduce software solutions that we can use to optimize material flows in various companies and also schools as teaching aid. For this we have chosen a few options that can bring new potential to a material flow optimization, these options are:

- VisTABLE.
- Tecnomatix FactoryCAD and FactoryFLOW.

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- Tecnomatix Plant Simulator.
- Autodesk Product Design & Manufacturing Collection.

2.1. VisTABLE

This software solution comes from the German company Plavis GmbH. It provides a wide range of functions for designers and industrial engineers to create a detailed layout. The visible tool is a program that helps in the static design of production systems. It is especially remarkable for its relatively specific functionality. It contains applications that facilitate the work of designers and decision-making in planning, the organization of the workplace, and the entire production organization. With the visTABLE software tool, we can intuitively plan production. With the grab and drop feature, you can create complex layouts in minutes. The intuitive operation works smoothly and allows workflow without significant knowledge of CAD tools. The software immediately acknowledges any changes in material flow, area usage, or safety distance. The unique combination of processes and projects helps streamline procedures and reduce logistics costs. Fig. 1. Shows the user interface of VisTABLE software.

Fig. 1 VisTABLE user interface [2]

2.2. Tecnomatix FactoryCAD and FactoryFLOW

FactoryCAD is a software add-on designed for the design of production and logistics systems. It adds new features to AutoCAD software that make it easier to organize production. It allows users to organize objects in 2D format and at the same time create 3D geometry in one software thanks to standard and custom parameters of "smart" objects [3].
FactoryFLOW is a software add-on that allows industrial engineers to optimize production plans based on material flow, shipping frequency and cost analysis. Like FactoryCAD, it is used as an extension to AutoCAD software, but unlike FactoryCAD, FactoryCAD adds new features and tools to the toolbar. It works in a separate window, but it cannot be run without AutoCAD. It is also used for workflow analysis and optimization of AutoCAD and FactoryCAD designs [3]. Both Factor CAD and FLOW are shown in fig. 2.

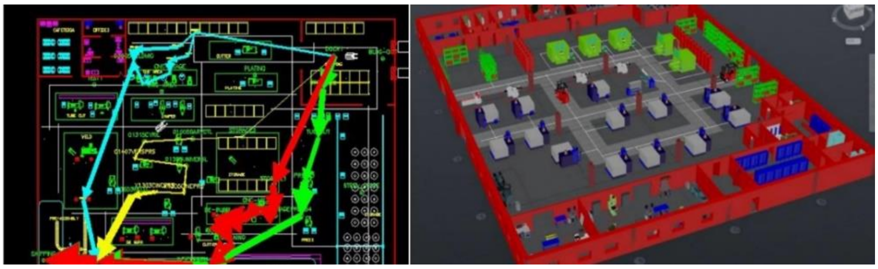

Fig. 2 FactoryCAD (right) and FactoryFLOW (left) [3]

2.3. Plant Simulation

Plant Simulation (Fig. 3.) is software from Siemens PLM Software that is used to model, simulate, analyze, display, and optimize production systems, processes, material flow and logistics operations. With this program, it is possible to compare complex production options, including internal processing logic, thanks to computer simulations [3]. Plant Simulation is used by small and large companies mainly for strategic planning of production distribution, management and control of process logic and the amount of capital investment in production. The software can import additional information from alternative systems such as Access and Oracle database, Excel or SAP.

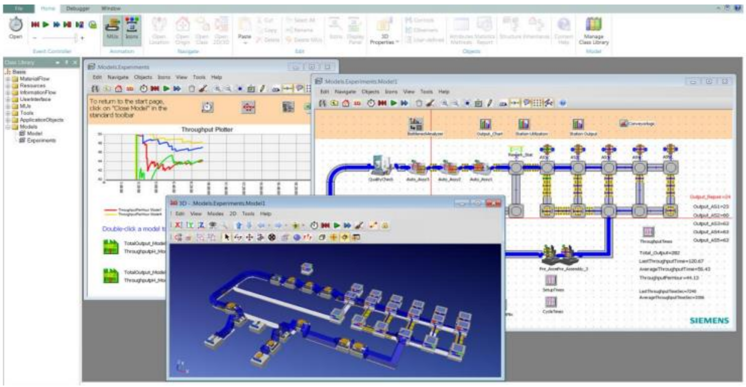

Fig. 3 Plant Simulation user interface [3]

2.3. Autodesk Product Design & Manufacturing Collection.

The Autodesk Product Design & Manufacturing Collection is a new collection of industry-specific solutions that have replaced the Factory Design Suite. An example of this software package is Autodesk PD & MC 2021, which aims to efficiently design machines tools, products or entire production lines (factory design). It provides all the tools for 2D and 3D design and presentation, from sketching and visualization to special functions of analysis, simulation, and design information management. When you buy a product, you get optimal, complimentary,

comprehensive tools that cover all phases (or at least an important part) of the designer's workflow.
Factory Design Utilities (FDU) is one of the additional software that includes the PD & MC package. Factory Design Utilities are 2D and 3D manufacturing and optimization solutions that can work with other Autodesk systems. This tool allows you to analyze existing 2D technical drawings (Fig. 4) to achieve an efficient material flow and transform project commitments into profit-generating assets. The time required for manual measurement can be reduced by incorporating scanned points to capture the factory condition [4].

Fig. 4 2D analysis in FDU [4]

3. CONCLUSION

The article presents one of the few possible solutions of the modern approach for material flow optimization either for practice or education. However, the important part of the process is choosing the paraments that are vital for the user and the chosen software should meet them. Therefore, this article should provide an overview of the solution currently available on the market.

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Zmiešaná realita, inteligentný výrobný systém, digitalizácia

Marián MATYS[1], Martin KRAJČOVIČ[2], Gabriela GABAJOVÁ[3], Dariusz WIĘCEK[4]

VYUŽITIE ZMIEŠANEJ REALITY V INTELIGENTNEJ VÝROBE

Abstrakt
Zmiešaná realita dokáže stále dôveryhodnejšie simulovať reálne prostredie a jeho činnosti, čo ešte viac rozširuje jej potenciálne využitie. Jednou z možností je jej aplikácia ako nástroja inteligentného výrobného systému (IVS). Článok prezentuje koncept virtuálneho prostredia inteligentného systému, ktorý zefektívňuje interakciu pracovníka a výrobného systému.

1. ÚVOD

Podnik súčasnosti je prepojená entita, veľa informácií je zdieľaných v reálnom čase do mnohých častí výrobného procesu a ďalších častí štruktúry podniku. IoT (Internet of Things) dnes umožňuje okamžitý prístup k aktuálnym informáciám a okamžitú reakci na ne, a to vstupom pracovníka, alebo autonómne priamo inteligentným systémom. Dôležitá je samotná interakcia pracovníka a systému, ktorá zabezpečí plynulý a efektívny priebeh výrobného procesu. Práve nástroje zmiešanej reality môžu byť použité ako metóda komunikácie človek-systém. Stupeň samotnej interakcie človek-systém závisí od úrovne interaktivity inteligentného systému, ktorú zmiešaná realita môže zvýšiť. Integráciou zmiešanej reality je možné vytvoriť plnohodnotné virtuálne prostredie prepojené s výrobným systémom, ktoré môže potencionálne zefektívniť rôzne procesy (obr. 1). Medzi tieto procesy môže patriť:

- vizualizácia výrobného procesu,
- sledovanie a diagnostika výrobného procesu,
- kontrola kvality,
- vzdelávanie zamestnancov,
- teleoperácia,
- návrh a optimalizácia výrobných a montážnych procesov.

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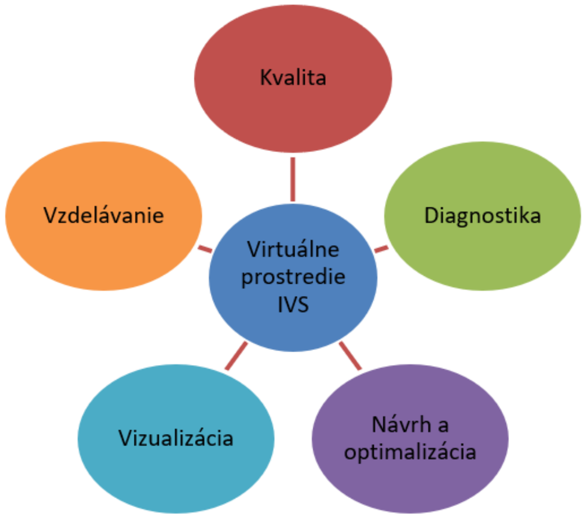


Obr. 1 Virtuálny priestor inteligentného systému (zdroj autor)

Pracovník by mal prístup k virtuálnemu prostrediu pomocou headsetu virtuálnej alebo rozšírenej reality (napr. HTC Vive alebo Microsoft HoloLens). Do systému sa môže dostať buď priamo na pracovisku počas výrobného procesu alebo počas iných procesov, ako napríklad vzdelávanie alebo zlepšovanie procesov.
Vytvorenie virtuálneho prostredia predstavuje digitalizáciu všetkých elementov výrobného systému, teda vytvorenie digitálnej repliky, ktorá dôveryhodne reprezentuje celý systém. Jej komplexnosť a interaktívnosť závisí od úrovne samotného prostredia, ktorú si zvolí firma. Dôležitým faktorom je taktiež prepojenie s reálnou výrobou, napríklad pomocou technológie IoT.

2. VZDELÁVANIE POMOCOU ZMIEŠANEJ REALITY VO VIRTUÁLNOM PROSTREDÍ INTELIGENTNÉHO SYSTÉMU

Virtuálne vzdelávanie je jeden z modulov virtuálneho prostredia inteligentného výrobného systému, ktorý sa však nachádza na okrajovej pozícii spektra. Zabezpečenie virtuálneho vzdelávacieho systému vyžaduje vytvorenie virtuálnej kópie výrobného systému, ktorá dokonale replikuje výrobné procesy, pričom zabezpečuje vysoký stupeň interaktivity. V tomto prípade je použiteľná virtuálna aj rozšírená realita. Jeden z príkladov je spoločnosť Volkswagen a jej „Digital reality HUB“. Ide o virtuálne prostredie, do ktorého sa zamestnanci môžu dostať pomocou VR headsetu. Toto prostredie poskytuje rôzne funkcie ako napríklad:

- virtuálne tréningy,
- virtuálne mítingy a kolaborácia zamestnancov,
- informácie o výrobnom systéme a teoretické podklady.

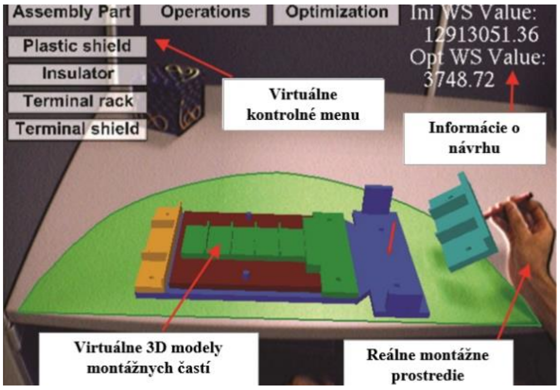
Systém dokáže zaškoliť nových zamestnancov a vytvára virtuálny priestor pre spoluprácu a sledovanie rôznych procesov. Ukážka virtuálneho prostredia je zobrazená na obr. 2.

Obr. 2 Digital reality HUB [1]

3. ZLEPŠOVANIE PROCESOV POMOCOU ROZŠÍRENEJ REALITY

Príkladom využitia zmiešanej reality pri zlepšovaní procesov môže byť plánovanie montáže s podporou rozšírenej reality. Manuálny návrh a plánovanie montáže je komplexný a časovo náročný proces, pri ktorom okrem technických a ekonomických faktorov treba zvážiť aj ľudský faktor. Na zefektívnenie tohto procesu môže slúžiť práve rozšírená realita vyvinutá tak, aby poskytovala vysoko intuitívne prostredie, ktoré umožňuje pracovníkom navrhnúť a plánovať montážne zostavy s dostatočnými informáciami o montážnom prostredí, a to aj počas skorého štádia návrhu. Rozšírená realita zlepšuje vnímanie informácií okolitého sveta pomocou kombinovania reálnych objektov s virtuálnymi, vďaka čomu môžu pracovníci manipulovať s virtuálnymi prototypmi a identifikovať nedostatky zostavy, pričom je všetko vykonávané v zmiešanom prostredí. [2]

Pri samotnom návrhu montážneho procesu môže pracovník komunikovať s inteligentným systémom a reagovať na zmeny. Môže tak dôjsť ku kolaborácií a návrhu jednotlivých postupov z optimálnej, ale aj ľudskej stránky. Obr. 3 zobrazuje návrh montážneho procesu pomocou rozšírenej reality.



Obr. 3 Rozhranie návrhu produktu pomocou AR [2]

Rozšírená realita úzko spolupracuje s CAD systémami. Vďaka čomu je možné využiť ich modelovacie jadrá na navrhovanie zostáv, pričom dochádza k zdieľaniu konštrukčných dát prostredníctvom aplikačného programovacieho rozhrania CAD systému [3].

4. ZÁVER

Predložený článok stručne popisuje koncept implementácie zmiešanej reality do inteligentného výrobného systému. Predstavuje vytvorenie jednotného virtuálneho prostredia, ktoré obsahuje rôzne nástroje pre zlepšenie procesov výrobného systému, ako napríklad virtuálne tréningy, či sledovanie a zlepšovanie procesov. Virtuálne prostredie umožňuje pracovníkovi efektívnejší prístup k informáciám a uľahčenie výkonu niektorých procesov. Všetko samozrejme závisí od technologickej úrovne a kvality implementácie. Zmiešaná realita ako technológia sa neustále vyvíja, hardvér bude neustále presnejší a dostupnejší, preto jej kombinácia s podnikovými nástrojmi sa v budúcnosti môže stať základom niektorých výrobných systémov.

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RTLS, network, localization

Marek MIZERÁK[1], Peter TREBUŇA[2], Ján KOPEC[3], Tomáš ŠVANTNER[4]

USE OF SPECIFIC LOCALIZATION ELEMENTS TO CREATE A DIGITAL NETWORK

Abstract
This article deals with the definition of the term RTLS location system and further discusses its main parts of which this system is composed. The article also describes in more detail the performance and parameters of individual parts and their function in cooperation with other parts of this technology. The conclusion of the article is devoted to the correct placement of this technology on various elements such as man, tools, or forklifts. In conjunction with these members of localization technologies, we can create a localization network for efficient collection of production data and subsequent possible optimization.

1. INTRODUCTION

Today, most large companies already use various monitoring or, in other words, localization technologies to streamline and innovate production. Many businesses are just realizing that digitization is an integral part of any "smart factory". Thanks to advances in today's technologies, managers and employees can rely on "silent workers" in the form of various localization technologies. These technologies, in conjunction with the company's software support, save money, reduce production times, ensure worker safety, and generally increase the general view of the manufacturing company's operations.

2. RTLS SYSTEM

UWB RTLS hardware from Sewio company consists of two types of hardware. The first type are signal transmitters, we know them as tags that are used to track objects. The second type

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of hardware is signal receivers, anchors used to receive signals from tags. We specify both species in the following subchapters.

2.1 UWB RTLS tags

Tags are small electronic devices that are attached to any object or person we need to track. The tags serve as signal transmitters, which then receive the anchors and forward the signal to a location server, where the position of the tags is calculated.

Sewio tags are characterized by high localization accuracy, up to 30 cm, and long battery life of up to 5 years. Battery life and life depend on how often the tag is updated during use. The tag can be equipped with a group of sensors, namely: accelerometer, gyroscope, magnetometer, barometer, thermometer, dosimeter, or others. The tags can work reliably at temperatures ranging from -20 to +60 ° C. Sewio location technology uses three types of tags: Tag Leonardo Personal, Tag Leonardo Asset and Tag Leonardo Vehicle.

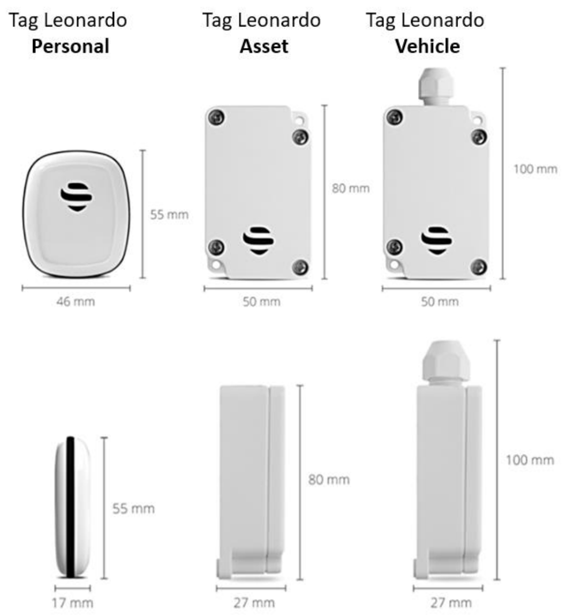

Fig. 1 Tags and their dimensions

The Leonardo personal tag is intended for the identification and location of employees, resp. other persons. In addition to industry, it is often used in healthcare, sports, retail and museums. Its task is to increase the safety of employees, navigate people within the monitored area, analyze the movement of employees and also replaces the classic methods of recording employee attendance.

It is equipped with UWB radio, NFC and Bluetooth technologies, LED indicators, allows wireless recharging, fast reconfigurability via RTLS Studio and is equipped with

an accelerometer and barometer to determine the Z-axis coordinate. It weighs 30 g and is equipped with a Li-Pol battery with a capacity of 300 mAh. The monitored persons most often wear it on their wrists in the manner of a wristwatch, it is also possible to fasten it on clothes or a safety helmet. The Leonardo Asset tag is designed to track and identify any asset. It is used for monitoring and analysis of material flows and in the e-Kanban system. It provides companies with a quick return on investment. Just as the personal tag is equipped with UWB radio, Bluetooth and NFC technology as well as an accelerometer, the barometer is missing. It is powered by a coin cell battery with a capacity of 1000 mAh without the possibility of recharging. It can be extended with a magnet for easy attachment to monitored objects. Its weight is 70 g.
The Leonardo Vehicle tag does not contain a battery and is therefore intended for monitoring devices that can power it. These are mainly forklifts and AGV trucks or milk runs in the field of intralogistics and storage. It is equipped with accelerometer, barometer, UWB radio, NFC and Bluetooth. It weighs 104 g. It is suitable for placement on the roof of the carts for easy signal transmission to the anchors.

Fig. 2 Example of placing a tag on a forklift roof

In order to obtain accurate and complete information about the location of monitored objects, it is also necessary to pay attention to the correct placement of tags on these objects. In the case of persons, attachment to the wrist, shoulder or safety helmet is recommended. The location around the torso is not suitable because the human body weakens the intensity of the UWB signal and it is then more difficult for the anchors to detect this signal. The principle of placing tags in their upper parts applies to forklifts and boxes. We try to prevent the signal from weakening by the monitored object itself.

Fig. 3 Appropriate / inappropriate placement of tags on objects

2.2 UWB RTLS anchors

Anchors are reference electronic devices with a known location, equipped with a Wi-Fi / Ethernet interface, which detect UWB pulses transmitted by tags. Their primary function is to collect the radio signal from the tags to calculate their position through RTLS Studio. In addition, they also receive data from sensors on acceleration, orientation, temperature or CO2 concentrations, etc. This data is further shared by users via the API. Anchors are usually installed above the height level of the tags, and thus in the ceiling spaces. This ensures maximum coverage of the monitored area and minimizes obstacles blocking data transfer from tags to anchors. Easy installation of anchors is possible due to their compatibility with different types of holders. If the area system requires coverage of the area, it is necessary to install a group of anchors to create a network infrastructure.
The Sewio RTLS system is fully scalable, and therefore the anchors allow the addition (removal) of an infinite number of tags within the monitored area. Due to the position calculation by the TDoA method, the anchors are characterized by robust time synchronization and resistance to signals from other devices. Thanks to UWB technology, the anchors can work even in environments with a high number of metal objects. For other radio technologies, the presence of metallic objects reduces the signal quality and thus the quality of the information obtained. However, UWB technology is ideal for industries where metal equipment forms the basis of production. The anchor housing ensures their resistance to dust, and thus their suitability for use in industrial environments. The anchors are equipped with an LED to check their condition and their restart can be performed remotely if necessary. This is a great advantage due to their location in hard to reach places.

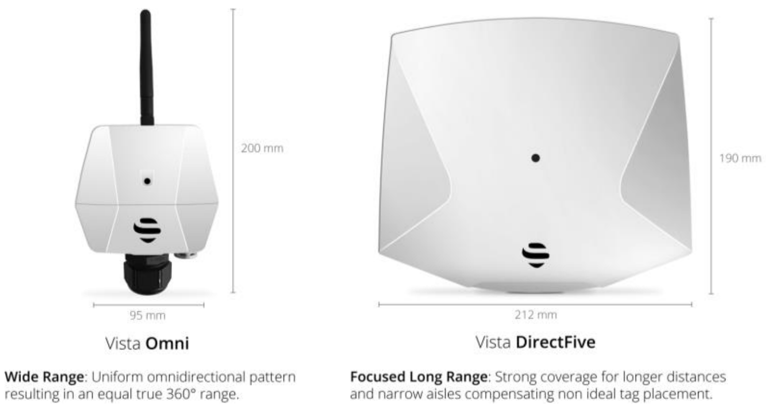

Fig. 4 RTLS anchors and their dimensions

The following figure describes how the Vista DirectFive anchor tilt angles are calculated. For the calculation, it is necessary to know the height of the anchors and the distance from the adjacent anchor. The monitored area of each of the anchors should not be greater than 25x25 m (625 m2), and thus the maximum distance between the anchors should not exceed 35 m. Using the properties of right triangles and trigonometric functions, the required tilt angle of the anchors can then be determined by simple calculations.

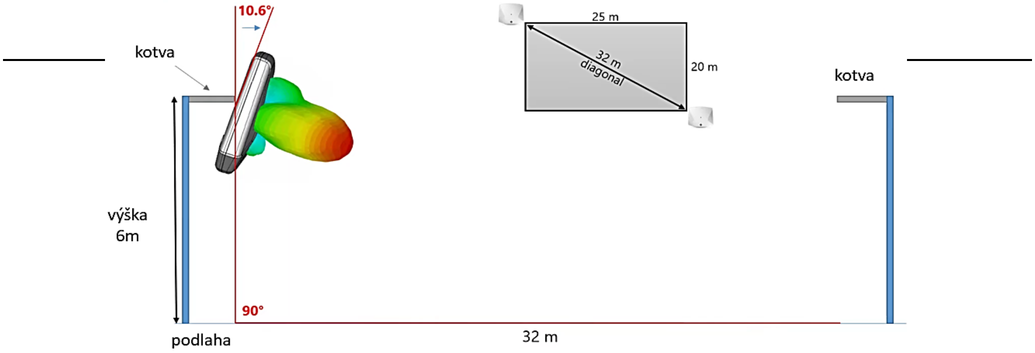

Fig. 5 Example of calculating the anchor tilt angle

In order to correctly determine the position of the monitored objects, it is necessary that the signal from each tag is received by at least three anchors. It is also true that the anchors can detect the signal only from tags whose direct distance to them does not exceed 200 m. The result of a combination of these factors is the need to create an anchor network. When designing the anchor infrastructure, it is necessary to take into account the environment of the monitored area, and thus the obstacles that could hinder the signal transmission (walls, racks, etc.). When creating a network, it is also appropriate to identify the places where there is the largest flow of materials and the movement of employees and forklifts. In these places, it is recommended to create a denser infrastructure to ensure maximum location accuracy.

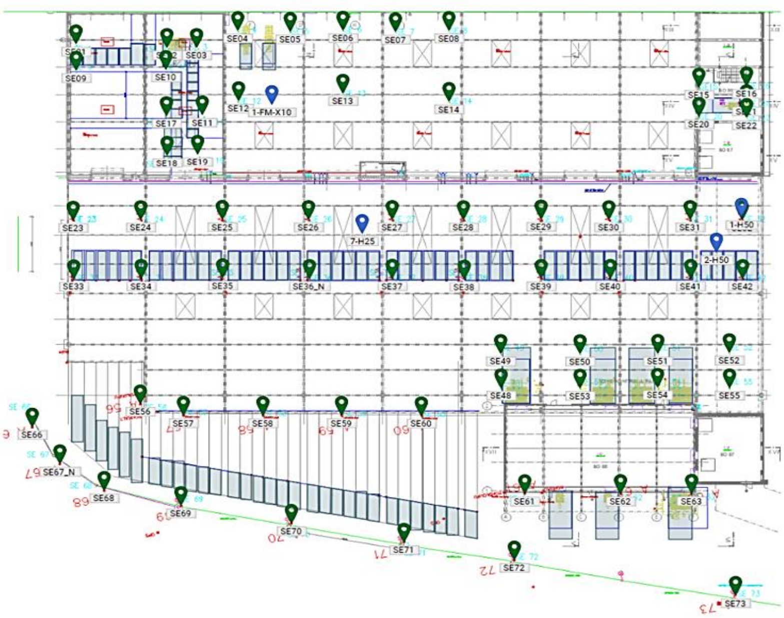

Fig. 6 Example of warehouse anchor infrastructure

3. CONCLUSION

The participating manufacturing companies and plants are subject to constant modernization, which is essential for success. The digitization of production data using elements of industrial localization such as RTLS systems is becoming more and more recognized. This is due to the results of these systems in protecting the health of workers, but mainly by saving production times, protecting assets and products and, last but not least, saving corporate finances. Within these applications, it is necessary to point out the importance of digital twins, which means the "mirroring" of physical classifications and processes, on the basis of which it is possible to visualize, evaluate and subsequently optimize the use of assets but also improve production. With this fact, industrial practice gains more control over everything that happens in production and thus increases the efficiency and productivity of business.

ACKNOWLEDGEMENTS

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Advanced industrial engineering, transport costs, optimization, Tecnomatix Plant Simulation

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OPTIMIZATION OF PRODUCTION DISPOSITION WITH REGARD TO MINIMUM TRANSPORT COSTS - CASE STUDY

Abstract
Cost optimization in production is a never-ending cycle of finding a bottleneck with its subsequent solution. The task of industrial engineering is to look for tools that will make finding optimal solutions easier and faster, for example, by means of simulation. In its content, the article discusses the description of a case study aimed at optimizing the production disposition with regard to the minimum transport costs. The solution is implemented using the LayoutOptimizer tool of the Tecnomatix Plant Simulation software.

1. INTRODUCTION

The layout of production always has an impact on the costs incurred by material handling. Therefore, the optimization of the disposition always has its place in the design of the production system. Many methods can be used to optimize the position [1]. In some cases, the path of physical testing is not a consideration, so the mathematical solution remains. Analytical mathematical solutions are inefficient and lengthy, for the calculation of which grows exponentially with the number of optimized workplaces. Simulations therefore play such an important role, as they allow reliable information to be obtained even with more workplaces [2]. Even in simulations, a higher number of workplaces increases the number of necessary experiments to get the best solution [3]. Therefore, optimisation methods are often used for which a certain criterion is selected, whether a special purpose function chosen or a value of one of the numerical characteristics [4]. The content of the article is a description of the Case study of optimizing the layout of 11 workplaces using the LayoutOptimizer function of the Tecnomatix Plant Simulation software.

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2. DATA AND METHODOLOGY

Today, many simulation tools allow for some form of model optimization. However, optimization and such is significantly limited by the number of optimised factors, and as they grow, the number of experiments is high. Therefore, many manufacturers implement the tools to deal with this problem. Tecnomatix Plant Simulation software includes a built-in tool that allows you to successfully optimize layouts through layout optimizer. The task that is designed for the solution is to detect such a set-up of production devices places so that the transport costs are as low as possible, given the planned production process and product mix. Fig. 1 shows the current layout of the production disposition designed for optimization.

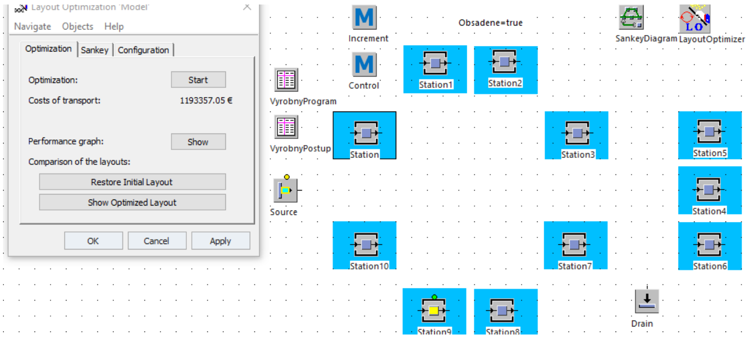

Fig. 1. Simulation model of production disposition before optimization

In the figure, possible workplace positions are highlighted in blue. There are 4 products on the line, the workflow of which is defined in Tab. 1.

Tab. 1. Workflow for manufactured products

Product A	Product B	Product C	Product D
Station7	Station	Station10	Station7
Station8	Station2	Station	Station4
Station3	Station7	Station3	Station3
Station	Station4	Station10	Station1
Station5	Station	Station2	Station8
Station1	Station4	Station7	Station1
Station	Station2	Station1	Station
Station8	Station7	Station6	Station10
Station5	Station3	Station7	Station1
Station9	Station4	Station8	Station7
Drain	Drain	Drain	Drain

The frequency of product entry into the system is defined as in Tab. 2.

Tab. 2. Frequency of entry of manufactured products into the system

Product	Frequency of product input
A	0. 25
B	0. 25
C	0. 30
D	0. 20

3. RESULTS AND DISCUSSION

If we experiment without considering reducing experiments, then the number of combinations is given as 11! which is 39,916,800 experiments. Since finding the optimal variant would be time consuming, a tool operating on the basis of genetic algorithms is used. The calculation function uses a Sankey diagram to help it determine the transport distances. Sankey's initial diagram is on Fig. 2.

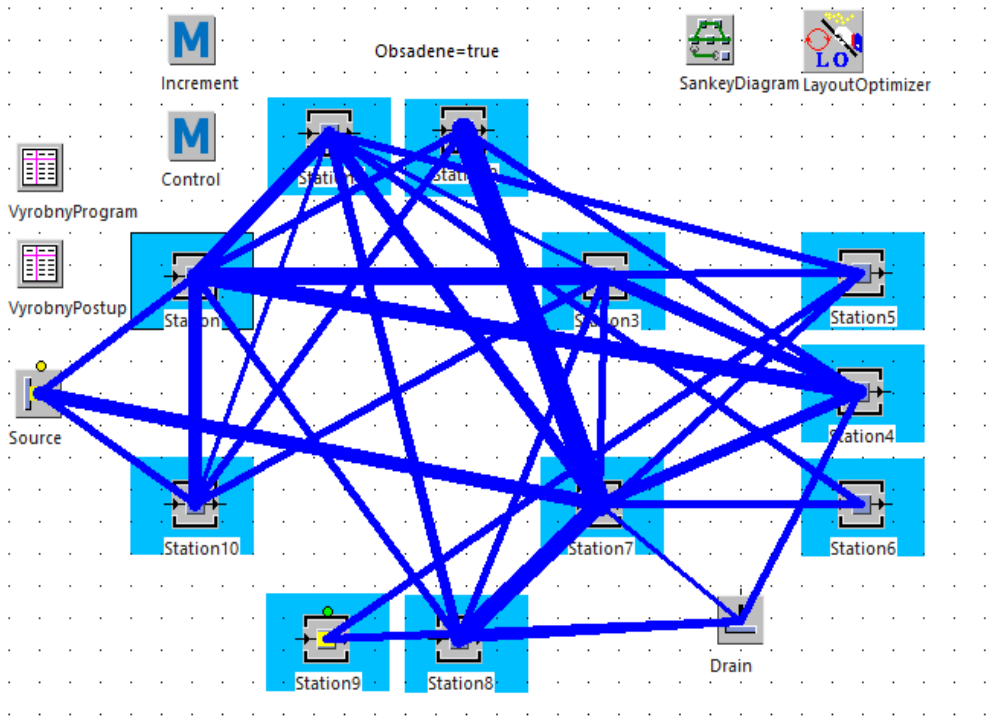

Fig. 2. Sankey diagram of simulation model before optimization

In order to determine the sub-optimal solution, it is necessary to define the workplaces that are subject to experimentation, the monitored entities, i.e. products, and to carry out an initialization run on the basis of which the calculations will take place. Then, when launched, the program performs the calculation through genetic algorithms and determines the found sub-optimal solution that sets and quantifys into its own financial statement. The result after starting a function with defined parameters is shown in Fig. 3.

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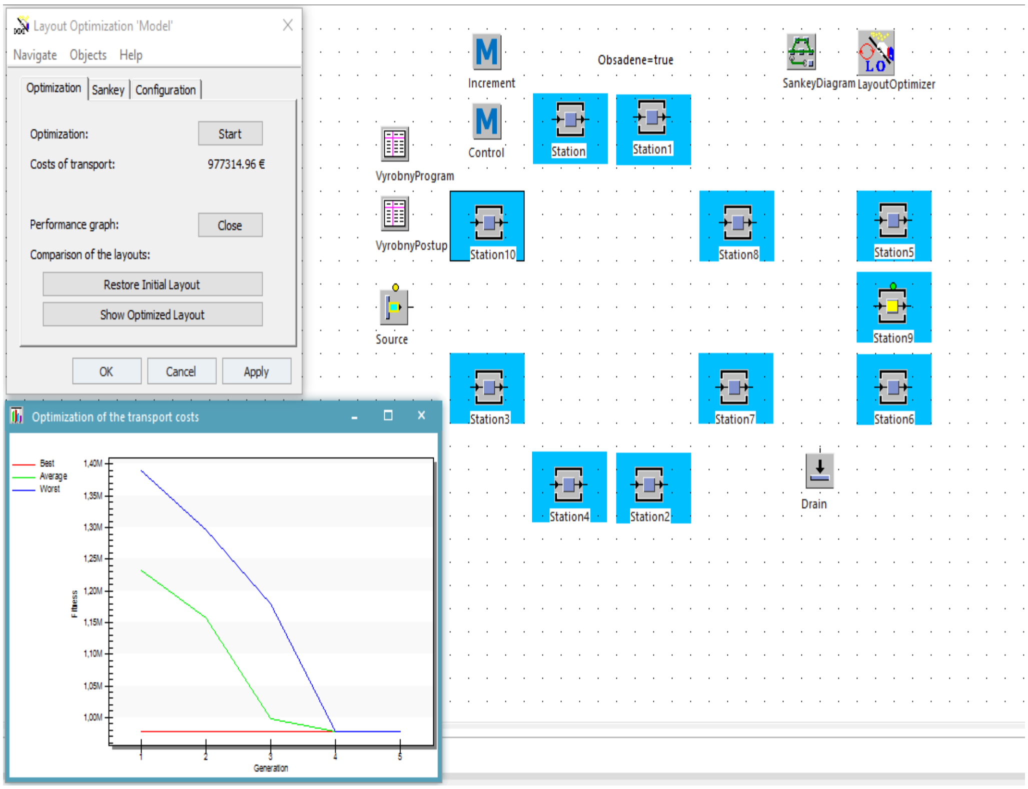

Fig. 3. Simulation model of production disposition after optimization with fitness progress graph for individual generations

As can be observed from the graph with 4 generations, we were no longer able to find a better solution, so a higher number of generations would have no meaning and the tool would end the calculation with 5 generations. Sankey's new diagram of the sub-optimal solution found is depicted on Fig. 4.

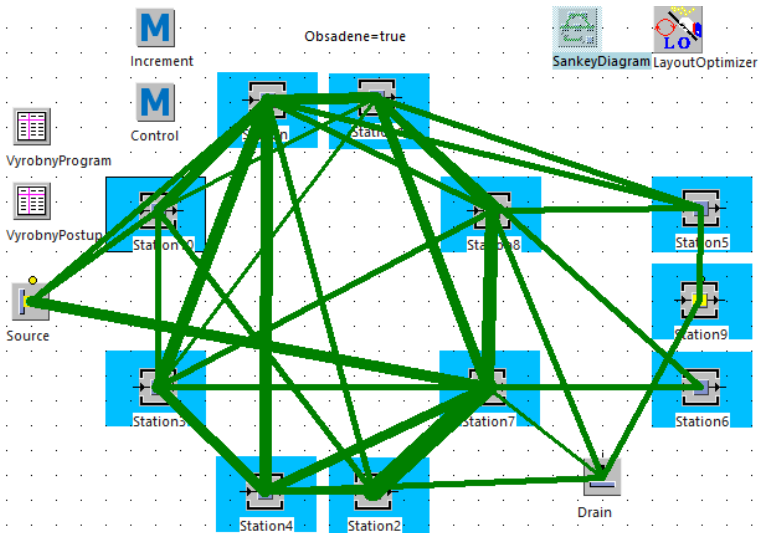

Fig. 4. Sankey diagram of simulation model after optimization

From the results themselves, it can be concluded that using the tool we were able to reduce transport costs and find such a sub-optimal solution that is satisfactory. The new solution itself represents a decrease of transport costs by 18.10% compared to the original location of workplaces.

4. CONCLUSION

Today, developments in the world can be observed in the world, especially in the field of digital technologies and computing performance. With this development come new possibilities in the field of solving the computational performance of demanding tasks. Various software companies, especially simulation tools, already offer various additional features that allow to involve various evolutionary optimization algorithms in the optimization. One of these softwares is also Tecnomatix Plant Simulation ten allows you to solve tasks related to the deployed resources in the layout and find optimal positions with a view of different limitations and required dependencies. The case study mentioned in the article modelled proved that when the new deployment is in the way of the new deployment, we can get savings of 18.10% especially in terms of transport costs, due to the current setting of the product mix. Such a tool can also be effective with regard to reconfigurable manufacturing systems, which thanks to modularity allow for a change of location in production and where it is necessary to constantly reassess the length of transport relationships to find the optimal configuration.

ACKNOWLEDGEMENTS

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AHP, exact methods, gender equality, employee selection, job position

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USE OF THE AHP METHOD IN EMPLOYEE SELECTION IN ACCORDANCE WITH THE CONCEPT OF GENDER EQUALITY AS A PART OF INNOVATIVE CHANGES IN SUSTAINABLE DEVELOPMENT

Abstract
The paper focuses on gender equality between men and women in society. An effort to balance gender equality bring better research results, support innovative changes, and increase their relevance. The main goal of the paper is to apply the method of multicriteria decision-making (AHP - Analytic Hierarchy Process) to identify based on selected criteria a suitable candidate for the position of Human Resources specialist with a focus on gender equality.

1. INTRODUCTION

Although the Covid-19 pandemic has slowed progress in gender equality, more and more countries and communities are aware of the need to revitalize efforts to achieve sustainable development goals, including gender equality. Despite the progress made in the field of gender equality, many systemic barriers persist that prevent the achievement of optimal gender equality in all areas.

2. THEORETICAL REVIEW

2.1 Managerial decision making and exact methods

The essence of decision-making is problem solving, while the main function is to choose (non-random selection) the most appropriate solution variant. Decision-making is an important part of managerial work at any management level. Every managerial decision is the result of a dynamic process of analysis and reasoning, which can be used to work on the result, the decision [1]. Exact methods can be included among the most used decision-making methods. Exact methods are among the most developed quantitative methods and their task is to find among the possible variants of the solution the variant that best suits the set goal [2].

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2.2 Gender equality

Gender equality, or equality between men and women in society, is currently one of the fundamental values of democratic countries and international institutions [3]. Ensuring gender equality, as one of the goals of sustainable development, contributes fundamentally to the prosperity of countries' economies [4] [5]. Although the issue of gender equality is one of the main priorities of the European Research Area Committee, this issue needs to be better recognized and accepted by most organizations. The European Commission has improved gender equality policies over the years and pursues the goal of embedding gender equality in research and innovation based on a gender equality strategy [6] [7]. Gender equality includes sections such as fair division of labor, recruitment, enforcement opportunities, wages, working conditions, work-life balance, access to education and the prevention of discrimination [8]. To ensure all of the above sections, a person (employee) who is able to include gender equality throughout the organization is needed. The work of a gender equality specialist includes the identification of shortcomings in the principle of gender equality and the subsequent implementation of corrective measures to improve the state of gender equality, gender mainstreaming, gender equality management, implementation of gender equality principles in personnel strategy, gender awareness , creation of projects focused on gender equality, knowledge and application of methodologies and best practices suitable for the implementation of gender equality.

3. DATA AND METHODOLOGY

The main goal of the paper is to select the most suitable candidate for the selected job position in accordance with the concept of gender equality on the basis of established criteria. We mainly used the analysis of current scientific research publications and multicriteria analysis with pairwise comparison. We used the method of multi-criteria decision-making of exact methods for decision-making - the method of the Analytical Hierarchical Process, which is used in decision-making processes in which several criteria and variants enter. This method is based on a pairwise comparison of criteria and variants [9]. Various software programs can be used to apply the AHP method. As part of the work was used ExpertChoice software. This software makes it possible to evaluate individual variants on the basis of criteria as well as to determine the order of variants [2]. At the beginning, we defined the main goal of the article. Defining the individual criteria according to which the selected adepts will be evaluated is after determining the main goal, another task in selecting the most suitable adept:

1. **experience in the field of Human Resources** – it is very important for work in each position to have at least 2 years of experience in the field of human resources management,
2. **experience in the field of Gender Equality** – it is very important for work in each position to have at least 2 years of experience in the field of gender equality,
3. **education in the field of Human Resources** - sociology, psychology, andragogy, HR,
4. **trainings and certificates** – in the field of gender equality,
5. **leadership** – the ability to lead subordinate employees towards an understanding of the essence and importance of gender equality between men and women,
6. **world language** – English at C1 level due to potential partnerships at international level,
7. **practice in project management** – in the field of gender equality.

8. ***job rotation rate*** – duration of employment less than one yeas = job-hopping.

Based on the structure of the criteria, an adept model with the required criteria was created. According to this model, a virtual personnel selection of potentially suitable adepts was performed. Adepts were selected on the basis of the above criteria for the position of HR specialist with a focus on gender equality from the business-oriented LinkedIn platform.
The variants represent four potentially suitable candidates for the chosen job position:
Adept A - 50-year-old Spanish man with more than 20 years of human resources experience, including 9 years as Director of Human Resources. He has implemented international projects aimed at equal opportunities and opportunities for men and women. He completed courses focused on gender equality. He speaks several foreign languages. Adept A did not graduate from college. He has always worked in individual job positions for several years.
Adept B – 31-year-old man, Slovak, with 4 years of experience in the field of gender equality. He graduated from college with a degree in Human Rights. He graduated from college in English (level C1). He coordinated international projects focused on gender equality. Job-hopper - changed jobs every year.
Adept C – 46-year-old woman, Czech Republic, with many years of experience in the field of gender equality in the ministry, but also in the organization. Gender equality auditor for companies and public institutions. She graduated from a university in the field of Social Policy. She has been actively working for 6 years on a project to combat gender inequality. He speaks English at the required level. She has always worked in individual job positions for several years.
Adept D – 57-year-old woman, Italian. She has 20 years of experience in the field of gender equality and 10 years of experience in the field of human resources. Own certificate: "Master at Gender Policies in the labor market and private and public companies." She graduated from the University of Economics. She coordinated gender equality projects in the workplace. He speaks English at the required level. She has been actively working in individual positions for a very long time.

4. RESULTS AND DISCUSSION

We entered the goal, individual criteria and variants into the ExpertChoice software in order to select the most suitable adept for the given job position. The next step in the decision-making process was a pairwise comparison of the individual criteria. All combinations of the selected criteria had to be paired. Numerical values 1-9 were used for pairwise comparison of individual criteria. The values of the criteria were determined by expert estimation. Based on the inputs, the software calculated that the most important criterion in selecting the most suitable candidate for the position of Human Resources Specialist with a focus on gender equality is gender equality practice and the least important criterion was the degree of job rotation.

Figure 1: The outcome of the decision-making process (Source: own processing of AHP Method in Expert Choice Software)

Subsequently, it was necessary to perform a pairwise comparison of selected alternatives (adepts), against individual criteria. From the Fig. 1 it is clear that Adept D was determined as the most suitable for the position.

5. CONCLUSION

Increasing gender equality is currently making a major contribution to the prosperity of the European economy and to increasing its competitiveness, because only through diversity can people reach their full potential. Choosing the right adept to ensure gender equality is a key decision for organizations that contribute to reducing gender inequality.
The use of the AHP method in the selection of suitable employees is very beneficial in the decision-making of human resources. Using ExpertChoice software, we have come to the conclusion that a woman with many years of work experience in the field of gender equality as well as in the field of human resources is a suitable candidate for the chosen job position.

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human resource management, Industry 4.0, COVID-19, industrial enterprise

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THE PERCEIVED IMPACT OF PANDEMIC RESTRICTIONS ON HUMAN RESOURCE MANAGEMENT IN INDUSTRIAL ENTERPRISES

Abstract
The aim of the research was to identify the impact of the pandemic restrictions on the performance of industrial enterprises in the perception of managers and employees. The results of presented research are based on data collected in two questionnaire surveys. The first survey was focused on the top management (n = 70) and the second survey was focused on employees of industrial enterprises (n = 287). The results showed that the implementation of Industry 4.0 have had a positive impact on the human resource management during the COVID-19 pandemic.

1. INTRODUCTION AND LITERATURE REVIEW

Human resource management is the process of managing people in an organization, which consists of human resource management functions, programs, and practices. Its aim is to meet corporate goals, but also the personal goals of employees. Human resource management functions are comprehensive specialized parts of the human resource management process. These functions have their goals and use specific methods to secure them [1 and 2]. Over time, human resource management has to cope with changes brought about by long-term trends, but also by sudden turbulence, such as the COVID-19 pandemic [3]. Technological or social changes have long shaped economies and the functioning of organizations. Long-term developments and changes in the functioning and management of organizations also have an impact on the demand for employees for specific professions. Long-term trends overlap and complement each other with short-term radical changes. In addition to gradual developments, corporate management must be able to cope with sudden changes or impacts, such

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as the financial crisis in 2008 or the pandemic situation in COVID-19 in 2020 and 2021. The closure or reduction of operations as a result of anti-pandemic measures has caused a shock for the economies of countries, companies, but also organizations [3 and 4]. Due to uncertainty and the crisis, individual areas of human resource management are also affected. Among the areas of human resource management, we can include [5]: recruitment and selection of employees, hiring of employees, presence at the workplace (home office), assignment of work tasks, training of employees, remuneration of employees, control of fulfilment of work tasks evaluation of employees, dismissal of employees and communication and information of employees.

In a study focusing on human resource management practices due to uncertainty and crisis, the areas of economic crisis, natural disasters and political uncertainty were identified as the main impact of crisis and uncertainty. In examining the impact of the economic crisis on human resource management, it emerged as an area that requires further attention, which is the role of socially responsible human resource management practices as part of strategies to address the impact of the economic crisis on human resource management [6]. The area of strategic human resource planning during economic turbulence also requires more research attention. Increased attention needs to be paid to general strategic planning techniques. The study also demonstrated the importance of resilience and agility during the global economic crisis. There is a need to examine information on the specifics of how human resource managers have been able to develop agility in organizations in times of economic turbulence [7].

2. DATA AND METHODOLOGY

Research data were collected in two surveys. The first survey was addressed to employees of industrial enterprises and focused on the perception of the impact of the COVID-19 pandemic on their work. 287 respondents took part in the survey. The questionnaire was distributed in paper form in person through instructed interviewers. Data collection took place from May to October 2020. Of the total number of 287 respondents, 28 worked in a production position, 91 in an administrative position, 47 in a specialist position, 39 in a managerial position, 62 in a part-time job and 20 respondents in an unspecified position. The second survey was addressed to senior managers working in top positions in industrial enterprises. Individual managers were personally approached with a request to complete an online questionnaire. 70 respondents participated in the survey addressed to experts in the field of industrial management. Data collection took place in autumn 2020. In both surveys, the anonymity of the respondents was maintained. The collected data were processed and evaluated in MS Excel.

3. RESULTS AND DISCUSSION

In a survey for professionals, senior industrial managers, in addition to the impact of Industry 4.0, we focused on how the COVID-19 pandemic affected individual areas of human resource management. The results are shown in Tab. 1.

Tab. 1. Areas of human resource management influenced by COVID-19 (own elaboration)

Areas of human resources	positively	negatively	insignificantly	missing	Total
recruitment and selection of employees	24	26	19	1	70
hiring of employees	15	31	22	2	70
presence at the workplace (alternative working modes, home office)	35	28	6	1	70
assignment of work tasks	11	27	29	3	70
training of employees	3	47	16	4	70
remuneration of employees	6	26	34	4	70
control of fulfilment of work tasks evaluation of employees	16	26	25	3	70
dismissal of employees	5	28	32	5	70
Communication and information of employees	27	21	20	2	70

The most negatively affected areas of human resource management were training of employees, hiring of employees, presence at the workplace and assignment of work tasks. A predominantly negative impact was identified in recruitment and selection of employees, but also in the control of fulfilment of work tasks. Remuneration of employees was affected mainly insignificantly or negatively. Remuneration is one of the areas that employees perceive sensitively.
In a survey of employees, we found out how employees perceive the impact of the COVID-19 pandemic on their working conditions in addition to the introduction of Industry 4.0. Based on the respondents' answers, according to their experience, the pandemic contributed to a faster implementation of Industry 4.0 elements. Respondents also stated that the introduction of Industry 4.0 in the company significantly affected the positive management of the pandemic situation. In the survey, the authors also focused on the impact of pandemic restrictions on the area of remuneration and which areas of remuneration they affected, the results of which are shown in Fig. 1.

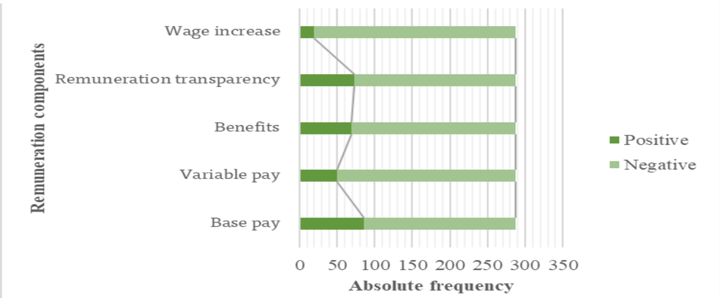

Fig.1. Impact of the pandemic on remuneration (own elaboration)

The results shown in Figure 1 show that the wage increase was largely negatively affected. On the contrary, the base pay component was affected mainly positively. Overall, we can state that all components of wages were negatively affected by the situation of COVID-19.

4. CONCLUSION

Human resource management in industrial enterprises is focused on recruiting, developing, maintaining and retaining a workforce. The employees represent an important source of efficient work as a prerequisite for the company's performance. Based on the presented results, we can state that the pandemic situation of COVID-19 has a positive effect on the implantation of Industry 4.0 elements. At the same time, we can state that the pandemic situation had a predominantly negative impact on employee remuneration. These findings are important in strategic HR management planning in organizations. The authors of the paper plan to focus on the impact of the COVID-19 pandemic on dismissal of employees as well as the management of outplacement programs in further research.

ACKNOWLEDGEMENTS

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3D modelling, marketing, production

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3D MODELLING AS A TOOL TO SUPPORT MARKETING

Abstract
Marketing is an essential part of the strategic planning and management of every company and allows them to find a market for their products and improve overall competitiveness. Our research focuses on the use of digitization and 3D modelling technology in MicroStation V8 software for marketing purposes. The resulting 3D models, examples of which are presented in this paper, can be used not only for design, optimization and planning but also as a graphic basis for marketing purposes concerning customers as well as potential investors of companies.

1. INTRODUCTION

The main initiators of developing new production approaches are becoming current trends in production, which are based on customization and gradual custom production. Each company's production depends on the demand for the products it offers. Every company must adapt to market conditions, global conditions, and constraints and constantly improve its competitiveness. Industry 4.0 technologies (such as digital factory, smart factory, 3D laser scanning, intelligent logistics, intelligent maintenance, etc.) in planning, management, maintenance, and logistics is nothing new. However, there are opportunities that we can use these technologies for marketing purposes. From the point of view of building a digital factory, these technologies are an effective and fast solution for achieving the company's goals in the Industry 4.0 concept. Of course, many companies already use software and hardware support, but they lack the extensive use of technology and methods. An example of such technology is 3D modelling. 3D models offer a wide range of uses in product promotion, especially in online shopping and online communication with customers and investors.

2. 3D MODELLING IN MICROSTATION V8 SOFTWARE ENVIROMENT

The MicroStation V8 software environment allows the user to create 3D models in eight different views. Four views are primarily used: TOP, FRONT, RIGHT, and ISOMETRIC. The user can select additional views according to needs and preferences. The dynamic rotation of the view

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and the adjustment of the primary views according to the location and rotation of the object in all three axes is a matter of course.
MicroStation V8 includes several hundred tools, some of which can be used at any time, and some can only be used for 3D drawing or 2D drawing. The tools are arranged and grouped according to specific logical rules into toolbars. The logical rule can be, for example, what types of elements the tools create or how to manipulate the elements. Each toolbar has its title, which can be considered what each tool can do. This title appears only in unexpressed (loosely spaced) toolbars (Fig.1. - red frame). Once the toolbar is docked at one of the edges of the program, its title visually disappears. Each tool on the toolbar has a display icon, a simple image that best describes how to use the tool.

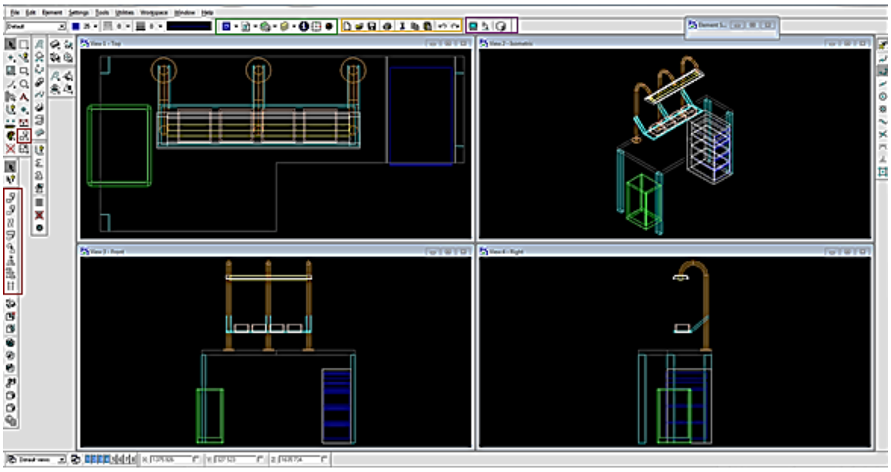

Fig.1 Environment of MicroStation V8 software

MicroStation V8 uses three unique panels. After clicking on the icon in these panels, the main thing is that there is no launcher, but they are used to working with the entire drawing. The first is the so-called standard panel which contains tools for creating, opening, saving, and printing a drawing, tools for the Windows clipboard, tools for undoing already performed operations, an icon for connecting to Bentley, and an icon for launching the wizard (Fig.1. – blue border). The second is the Attributes panel which contains items for setting active elements. Each object and group of objects has its characteristic attributes, such as the level (layer) to which the color, thickness, and line type belong. There is also a visual display in this panel of the individual attributes of the graphic display (Fig.1. – green frame). The basic toolbar's last panel contains items that open essential and frequently used dialog boxes (Fig.1. – yellow frame). Of these three unique panels, it would be worth mentioning the image control panel, which is for the user in complex drawings and can crop, indicate the active view in other (inactive) views, and render the object in its entirety, not only according to the outline of the render (Fig.1. - purple frame).

These tools make it possible to model 3D objects with different requirements and details. A good example is the manual workplace model in an industrial enterprise. The manual workplace can be modeled with minor details (Fig.2.) and capture only the spatial volume of the workplace. The high-detail model can be used for broader applications but is more challenging to create.

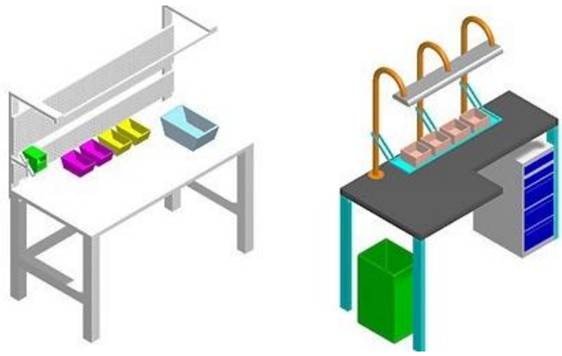

Fig. 2 3D models of the manual workspace

The model of the manual workplace shown in Figure 2 on the right is a work table and above the table is a broken lamp that draws a 3D tool that defines the shape of the body profile and the body axis (plane and line). The boxes under the table have carved bodies in each other, grooves cut in a line. The drawing shows the profile of the lamp with the inserted visualization of the bulb.
Another advantage of modelling is the creation of pallets and boxes that do not have freely available digital models for the factory's needs or have non-standard dimensions (Fig.3.).

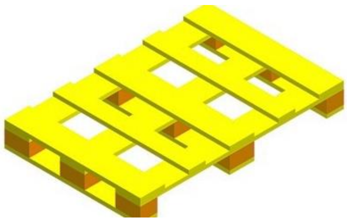

Fig. 3 3D model of the pallet

Models created primarily for visual purposes are mostly processed in standardized colors, such as metal structures drawn in turquoise, lamps in yellow, platforms in red, etc. In this way, we are able to model the entire production hall (Fig.4.) as a building with all equipment (pipes, ventilation systems, electrical wiring, various steel structures, conveyors, various transport systems, etc.), machines, manual workplaces, automatic lines, but also offices and common areas. The visualization can be displayed in the actual state, with all the inaccuracies and details exactly according to the actual state or in the ideal state according to the standardized dimensions.

Ideal models are used for advertising visualization when it is not necessary to take into account the external influence on the digitized object.

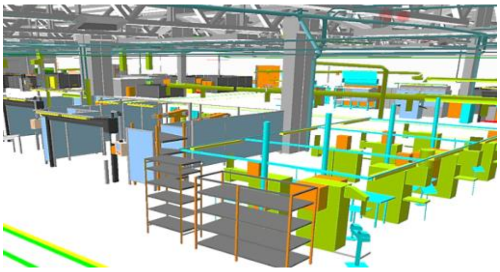

Fig.4 3D model of a production hall

3. USE OF 3D MODELS FOR MARKETNG PURPOSE

The entire digitization path begins with a collection of current status and creating the current state model. 3D models are currently a trend in planning, managing, and optimizing the entire manufacturing process but are also applicable to marketing purposes. The basic goal of marketing is to focus on the customer and satisfy his needs. The extent to which a company approaches its customers will largely determine its market position and future rise or fall. The second no less important goal in the conditions of a market economy is, of course, the creation of a reasonable profit, from which the further development of a company or organization is financed. Marketing is applied in the sphere of business as well as in non-profit organizations, but there are mainly cultural and educational facilities, charities, and the like. Visual advertising is currently a very common way of promoting sales. 3D models can be used as a visualization of the products that companies offer. Type of 3D product models can improve the customer's image of the product, for example, for companies that offer products such as furniture (Fig.5.) personal accessories, such as jewelry, glasses (sunglasses and eyeglasses), and clothing.

Fig.5 Demonstration of a 3D model of a couch in real space using augmented reality

The customer can try such products by using augmented reality. Today's technology offers the use of augmented reality directly in smart devices, such as smartphones or tablets. With this device, the customer can compare the 3D model to himself and better decide whether to buy the product. This ad is widely used for online shopping. An example is shown in Fig.6., which shows 3D models of machines and an industrial rack in an augmented reality environment on a tablet.

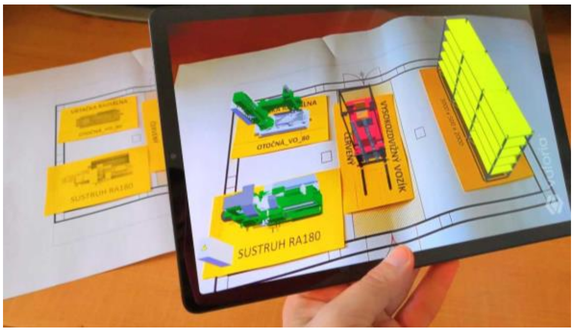

Fig.6 Display of augmented reality machines on a tablet [4]

This advertising system is focused on individual customer needs, customer values, and critical competencies. For regular customers, 3D models represent the possibility of comparing a product that the customer already owns from a specific company and a new product that he is interested in. Visual perception is significant when deciding to buy a new product that would be able to replace the product that the customer has already fully. The 3D models of machines, workplaces, and other production elements can be used as background images for large-scale advertisements for the company or promo videos.

In addition to the communication policy, 3D models can also be used in marketing production policy. For example, using 3D models, we can visualize the range of products with all variants while saving costs and time by comparing other methods for the range database. The use and demonstration of new technologies arouse interest among new investors and partners. Using 3D models, a point cloud obtained from 3D laser scanning, creating a virtual tour of the entire company is possible. In this way, it is possible to present the company visually to anyone anywhere. The virtual tour can be processed as a video, i.e., a pre-prepared visualization, which can no longer be entered and changed. The second way is a virtual tour in real-time, where it is possible to walk through the individual points and watch the individual elements from a specific place at a specific distance. The most effective way is to create a 3D model of the entire hall or the whole complex of the company in a virtual reality environment.

4. CONCLUSION

The long-term sustainability of the enterprise requires constant attention to the continuous improvement of business processes and systems so that the enterprise is still competitive in a dynamic and turbulent market environment. The optimization should dynamically occur according to the situation occurring in the production and the world.

The main findings of this study can be summarised as follows:

- digitization is a necessary response to a pandemic situation,
- digitization needs to be done quickly and efficiently,
- the most suitable tools for digitization are from the concept of Industry 4.0,
- the results of digitization are suitable input data for marketing,
- the use of 3D models in marketing has a wide range of applications concerning customers and potential investors.

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Kanban, storage, supply system

Jozef TROJAN[1], Peter TREBUŇA[2], Marek KLIMENT[3], Michal DIC[4]

STORAGE SYSTEMS AND THEIR INFLUENCE ON THE PRODUCTION SYSTEM

Abstract
This paper deals with the optimization of the warehouse system, inventory policy and production system supply system. The study will also answer the question of how these optimization steps will affect the production system. The aim is to find out what effect a suitably designed storage system and supply system have on the production system.

1. INTRODUCTION

An important task of logistics is to ensure the supply of production and the related suitable storage system. This contribution is dedicated to a railway car repair company that was until recently owned by another company. After the acquisition by the current company, the company's management decided to completely restructure. As part of this restructuring, the state of stocks, warehouses and the method of supplying the production system were optimized, among other things. The main problems of the company were:

- high level of stocks - a large number of types of items that have not been used are stored,
- large decentralized warehouses - ten different storage spaces throughout the company's premises and in most cases unused in terms of capacity,
- production supply system - the supply took place from a large number of storage places over long distances, thanks to which the supply was slow and inflexible.

The study was divided into the following sections:

- inventory quantity optimization - inventory turnover analysis,
- storage system optimization:
  - dimensional and weight analysis of stored items,
  - analysis of the current method of storage,
  - creation of a storage system,
- creation of a supply system.

The main goals of the study were a drastic reduction of warehouses and streamlining of production supply, while maintaining the performance of the production system.

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2. INVENTORY QUANTITY OPTIMIZATION

The company is engaged in repair, so the inputs to the production process are mostly spare parts. A large number of these spare parts have been used in recent years. The main problem of the company at the time of the analysis was the high level of stocks, from which the need for large warehouse space used to follow. However, they were not fully utilized at the time of the analysis in most cases. Therefore, the first step was to analyze the current state of inventory, using information obtained from the enterprise information system. During the analysis, the turnover of individual items and the time when they were last used were determined. Thanks to custom production and many years of experience with repairs of railway cars, it was possible to determine the required amount of stored items so that the production process was smooth. The items were then divided into the following categories:

- long - term unused items,
  - part of the items is to be disposed of or sold,
  - the part with the potential for close consumption is kept outside the usual storage premises,
- items commonly used - this category will be worked on in the future and will be updated once a month,
- items for maintenance by an external company,
  - small items (small electrical components, screws, nuts, ...) - items are provided by the kanban system (more about kanban in the next course level),
  - paints, varnishes and thinners.

3. STORAGE SYSTEM OPTIMIZATION

Another problem was the large warehouses located in various places throughout the company. The task was to centralize these warehouses and their storage areas in one place as much as possible. The first step was a physical analysis of the current state of stored items. The dimensions and weights of individual items were determined, the current method of storage was monitored and an approximate method of their future storage was proposed. The analysis revealed the following shortcomings in the storage of individual items:

- insufficient utilization of warehouse capacity,
- insufficient use of shelf loading areas,
- insufficient use of rack field height,
- for small parts, unsuitable way of storage on a shelf (in temporary packaging - boxes, cups, etc.).

Furthermore, the extent to which proprietary storage technologies can be used was ascertained. After dimensional and weight analysis, together with an analysis of the type of storage, a design of storage technologies was made:

- use the existing shelving system supplemented by boxes for storing small parts – the boxes can be stacked in the shelf and thus make better use of the entire shelf space of the shelf (Fig. 1),

- or buy a paternoster rack for small parts - the technique for rotating the racks increases the space requirements of the rack, but it is possible to use a larger potential height of the warehouse (Fig. 2).

Fig.1. Storage boxes

Fig.2. Paternoster rack

As a result, the storage area of both technologies is comparable, while the paternoster system enables faster identification of the item's position and, consequently, its removal. What other advantage can be mentioned higher safety at work, when the operator stays on the ground, without the need to use handling means to remove the item from the classic rack. The higher price of this technology proved to be a disadvantage.For the rest of the items use current storage technology: cantilever racks, metal stands, glass, etc.
After applying the proposed storage technology and reducing the number of stored items, the following warehouses were created:

- central warehouse - located in the main hall, where production takes place (production was also optimized during the restructuring and some workplaces were canceled or reduced. This created free space in this hall),
- warehouse of large parts (wheels, gears, ...) - located due to the considerable space requirements outside the main hall - in close proximity,
- external company's warehouse for supplying small items - located directly in the production area,
- external company's warehouse for the supply of paints, varnishes and thinners - located in one of the buildings on the company's premises.

Thanks to this reduction in the level of stocks and modification of the storage technology, there was up to a 50% saving in storage space compared to the original state of the storage system.

4. CREATION OF A SUPPLY SYSTEM

The last task was to create a supply system. The supply took place from several warehouses. From there, the items were transported to the two item transfer points in the production hall by means of handling means. These places are located at the entrance gate to the hall. From there, the items were picked up by individual work crews that move in the production system. As a result, supply was slow and inflexible.
The first step in streamlining supply was the reduction of the number of warehouses (see optimization of the storage system) and the transfer of responsibility for the supply of small items, as well as coating materials, to external suppliers.
The second step was to create transfer points directly in the production area. The storage of the usual amount needed to repair one railway car was also proposed at these transfer points. The position of the places was determined on the basis of an analysis of the movement of platoon in production (platoon has a certain space where they move together with the product - railway car), so that the distance between the place of work and the place where the material is prepared is minimal. Thus, 10 transfer points were determined for 30 working crews, where some places are used for more crews-

5. CONCLUSION

The whole project was designed so that the individual stages followed each other and create a common effect, i.e. the downsizing of warehouses and the optimization of the production system supply system. The first part was focused on the size of storage space, which achieved a reduction in the area of necessary storage space by 50% compared to the original state. This effect was achieved by reducing stored items and optimizing storage technology. In the second part, a supply system was designed, which increased supply flexibility and reduced the unproductive time of work crews (crews have the necessary inputs to production near workplaces ready). The effects obtained were savings in warehouse operation costs, reduction of funds tied up in stocks and reduction of non-technological times in production

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Reconfigurability, algorithm, reconfigurable manufacturing lines

Vladimír VAVRÍK*, Štefan MOZOL**, Patrik GRZNÁR***

THE UTILIZATION OF THE LONGEST COMMON SUBSEQUENCE ALGORITHM FOR CREATION PRODUCT FAMILIES

Abstract
The article describes the creation process of the product family using the LCS algorithm. This concept is presented via the short example of joining two products together. The conclusion of this article contains recommendations for future research in this field.

1. INTRODUCTION

We rank this algorithm among the typical representatives of dynamic programming. Its most important use is especially in DNA structure analysis, bioinformatics and molecular biology. The LCS (Longest Common Subsequence) algorithm works on the principle of finding the longest common substring (the longest sequence of characters from right to left, which must be consecutive), which is located in both strings. Suppose, therefore, that we have given two strings x and y with lengths of n and m characters, the task is to select the longest possible sequence of characters from the first string such that the whole is in the second string. For example, suppose the string $x \rightarrow$ "ABCDEFGH" (n = 8) and $y \rightarrow$ "ABCDGH" (m = 6) and thus their common longest string is "ABCDGH".
Thus, this algorithm can be a potential benefit for merging products into product families. The approach of product families is typical for reconfigurable production systems, while the following example was just part of the methodology of designing a configurable production system. This procedure is therefore a specific part of the methodology described in more detail in the article "The design of production lines using the principle of reconfigurability"
In the developed methodology is used mainly to identify the longest joint sequence of operations of two or more mutually similar products in creating a product family. Another area of its implementation in the methodology is to determine the similarity of product pairs, in order to determine the overall similarity between products [1,2]. We will describe the function of the mentioned LCS algorithm for the proposed methodology on a sample

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solution. The above symbolism of the designation is identical to the proposed methodology (in the article above) for a better understanding of the overall solution.

2. THE EXAMPLE OF USING LCS ALGORITHM FOR PRODUCT FAMILY CREATION

Let us imagine that we need to place two/three or more similar products on the production line, but these products contain some identical or similar operations. How can we avoid wasting production system resources and easily verify product similarity?

This algorithm can be the answer to this question because the algorithm makes it possible to identify identical operations (character strings) on products and thus consider common workplaces by simple recalculation and to optimize product logistics routes.

The input parameter for the algorithm is a set of matrices of operation types $NAME_{kn,\dots,km}$ and matrix $NAME\alpha$, depending on the need to use the algorithm. We will illustrate this example on a pair of products defined by the following matrices (Fig. 1):

$$NAME_{k1} = \begin{bmatrix} B \\ D \\ C \\ A \\ B \\ A \end{bmatrix} \qquad NAME_{k2} = \begin{bmatrix} A \\ B \\ C \\ B \\ D \\ A \\ B \end{bmatrix}$$

Fig. 1 The matrixs of products K1 and K2 with they operations stages.

From the displayed matrices we can determine the table (Tab. 1), on which it is easier to explain the principle of operation of the LCS algorithm. One of the matrices will be a row and the other a column of the table, it does not matter to determine this position when clarifying the principle, because the results differ only to a negligible extent.

Tab. 1 The initial table for LCS algorithm matrix

	K2	$NAME_{k1}$	$name_{11}$	$name_{21}$	$name_{31}$	$name_{41}$	$name_{51}$	$name_{61}$
K1			B	D	C	A	B	A
$NAME_{k2}$		0	0	0	0	0	0	0
$name_{11}$	A	0						
$name_{21}$	B	0						
$name_{31}$	C	0						
$name_{41}$	B	0						
$name_{51}$	D	0						
$name_{61}$	A	0						
$name_{71}$	B	0						

The first rows of a table constructed in this way must have a value of zero, while their function is explained by two conditions. however, we must try to define a matrix $LCSA$ for the pale area of the created table.
We are starting to fill in the empty fields of the table from left to right in columns. When filling in the table, we assess the values of the elements of the matrix $NAMEkn$ and $NAMEkm$ based on the following conditions (A) and (B). If for the element of the matrix xij there exists a corresponding row and a column with the same type of operation, then it is possible to apply the first condition (A). The contingency condition defines that the diagonally adjacent element of the xij considered is increased by 1. If there is no agreement between the matching row and column operations, we apply the second condition (B). The conditions A and B can be seen on the picture above (Fig. 2).

$$if\ (name_{ij})_{kn} = (name_{ij})_{km}, then$$

$$x_{ij} = x_{i-1j-1} + 1 \qquad \text{(A)}$$

$$if\ (name_{ij})_{kn} \neq (name_{ij})_{km}, then$$

$$then\ choose\ a\ higher\ value\ x_{ij}$$

$$x_{ij} = x_{i-1j} \qquad \text{(B)}$$

$$x_{ij} = x_{ij-1}$$

Fig. 2 The basic conditions for computation LCS algorithm.

If there is no agreement between the operations, it is necessary to get the same value for the element xij from the pair of elements. We therefore consider the element adjacent to the left and the element above the parent element. If the elements and operations in the row have been verified, we continue one row below and the same approach applies.
After filling in the whole table we will have a numerical path defining the longest common subaccessibility of the verified matrices. When evaluating, it is possible to determine two directions of the journey, always starting in the lower right corner from the highest number of the table. The first road has a defined direction on the left, while the second road has a defined direction up. We always choose one of the approaches and continue in that direction if the neighboring value of the current position is lower, and thus exceeds the marked areas in the table. If we come across a lower value, and thus an adjacent area, we jump to the diagonal element of the current one. Then we continue in the preselected direction of the path up to the zero row or column of the matrix $LCSA$.
The table with the marked path (green color) is given below (Tab. 2). The table also shows the areas of the jump to the diagonal element (red color). These elements xij matrices $LCSA$ actually define the longest common underflow of types of operations in the reverse order.

Tab. 2 The final table for LCS algorithm matrix

	K2	$NAME_{k1}$	$name_{11}$	$name_{21}$	$name_{31}$	$name_{41}$	$name_{51}$	$name_{61}$
K1			B	D	C	A	B	A
$NAME_{k2}$		0	0	0	0	0	0	0
$name_{11}$	A	0	0	0	0	1	1	1
$name_{21}$	B	0	1	1	1	1	2	2
$name_{31}$	C	0	1	1	2	2	2	2
$name_{41}$	B	0	1	1	2	2	3	3
$name_{51}$	D	0	1	2	2	2	3	3
$name_{61}$	A	0	1	2	2	3	3	4
$name_{71}$	B	0	1	2	2	3	4	4

The resulting subaccessibility can therefore be written as the reverse order, where the resulting matrix of these elements is denoted in the methodology as $LCS\alpha$ (Fig. 3).

$$LCS_{\alpha} = \begin{bmatrix} B \\ D \\ A \\ B \end{bmatrix}$$

Fig. 3 The final matrix for two products - only matches operations stages.

3. CONCLUSIONS

In the modern industry, we must search for new ways for optimizing and effective manufacturing products. This article represented just this nonstandard way for optimization using the LCS algorithm. This algorithm was used for the determination of similar operations for two products of the family. This is only one example, but we must look new opportunities to increase the efficiency of manufacturing in different areas and use this new solution for actual problems in the factory.

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Smart Factory, production monitoring, product life cycle

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MODERN APPROACHES TO MONITORING AND REGULATION OF THE PRODUCTION OF CERAMIC MATERIALS

Abstract

This article describes the issue of monitoring and regulation of production in the production of ceramic materials, specifically the approaches and methods of introducing life cycle monitoring of ceramic products. In order to be able to monitor the product life cycle and assign a separate birth certificate for each product, it is necessary that the production system has elements of monitoring and production control, which are based on the principles of Smart Factory and Industry 4.0.

1. INTRODUCTION

For every company and production system, the priority should be to stabilize production and increase its productivity. One of the leading concepts within Industry 4.0 is Smart Factory. This concept summarizes the approach to the automatic production system, which is able to monitor itself and, based on external and internal parameters, regulate production processes. For large industries such as automotive, there are established procedures and approaches to production management and monitoring, and very often these methods are already implemented in production. One of the tools used is product life cycle monitoring, which is only possible thanks to the introduction of advanced production monitoring systems. In traditional industries, such as the ceramics industry, which also includes the production of refractory materials, these processes are less well known and often inapplicable in automotive applications. When implementing Smart Factory principles in the ceramics industry, it is necessary to address a number of factors and variables that are specific to this industry. In the content of this article, these factors will be named and the framework of activities leading to the introduction of the possibility of monitoring the life cycle of ceramic products will be determined, both in production and in their use in applications. This is possible by assigning a product birth certificate to a specific product, in the form of an ID [1] [2].

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2. MEANS OF MONITORING AND REGULATING THE PRODUCTION SYSTEM

The goal of modern manufacturing companies is to achieve the principle of the Smart Factory - simply put, it is a production system that monitors and manages itself based on information from the production process and input information about orders and production plans. As part of the implementation of the Smart Factory and Industry 4.0 concept in the ceramics industry, several areas of production need to be addressed from the point of view of monitoring and regulation. These areas are unique to the ceramic industry.

Areas for implementing tools of Smart Factory in ceramic industry:

- Development of a methodology for monitoring and optimizing the storage of clay and other binders in order to identify and regulate its moisture.
- Development of systems and sensors for effective evaluation of the input mixture moisture.
- Development and implementation of a system for automatic shape creation (pressing) and its control in the raw state
- Development of a system for monitoring kiln wagons and their flow through the production plant.
- Firing control and monitoring system and optimized operation of kilns, including identification of wagons passing through kilns.
- Development of automatic final inspection, sorting, marking and packaging. [1]

To achieve the Smart Factory principle in the ceramics industry, it is necessary to solve all these partial development and implementation tasks. From the point of view of the introduction of the birth certificate (ID), monitoring systems of these technologies are necessary, thanks to which the movement of each product in production is completely monitored throughout the production period. It is also necessary to realize that production technologies, including handling, must be automated in order to continuously monitor the entire process. In the ceramics industry, automation brings additional benefits in the form of reduced scrap - raw ceramic products are non-rigid or brittle and product shape errors occur during manual handling. [4]

From the point of view of implementation and use of sensors, there are a large number of devices on the market that can fulfill this function. However, there are fewer such devices for applications in the ceramic industry, thanks to the properties of the raw materials. For example, when checking the humidity of a mixture, there is a big difference between whether the mixture will be measured in the laboratory (currently the most common solution) or whether an in-line inspection will take place on the conveyor. For the operation of the Smart Factory principle, it is not possible to manually enter the results of laboratory tests, but it is necessary to measure the parameters of the mixture and products directly on automated production lines. The introduction of the principles of automation and production monitoring brings, in addition to qualitative and economic benefits, also the opportunity to introduce the principle of product life cycle monitoring - the creation of a product birth certificate. [5]

3. IMPLEMENTATION OF PRODUCT'S ID – CASE STUDY

Thanks to the introduction of the product birth certificate - Product ID, it is possible to monitor production parameters essentially online within the production system, but also to collect data on the relationships between the resulting product quality and production parameters. Another very advantageous use of this data is the traceability of production parameters and input materials of production even after application in a given unit or function. Therefore, if a product fails or is destroyed several years after the sale and application, it is possible to retrospectively monitor the parameters under which it was manufactured and determine whether the cause of the product failure was not faulty production. Fig. 1. shows the basic scheme of production of ceramic chimney pipe (CCP), which is a representative of refractory ceramic products. The rough production process is described in square fields, oval zones represent data collection within individual technological sections and colored arrows represent the direction in which data from the given sections are used in other sections. This is a basic scheme of the method of monitoring and regulation of production. [3]

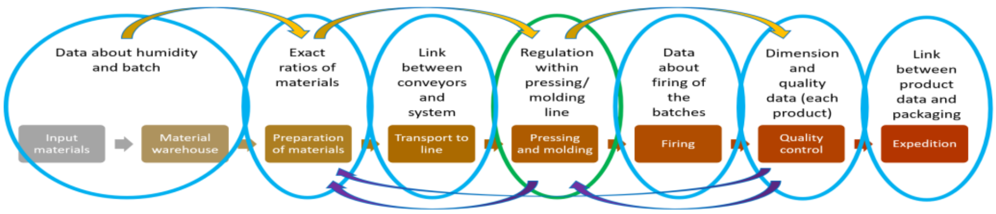

Fig. 1. Scheme of desired production data and information flow

In the case of ceramic chimney pipe production, it is possible to describe a case-study of the introduction of a product birth certificate. From the diagram in Fig. 1. there is a need for unambiguous identification of each ceramic chimney pipe with a unique character, also referred to as "CCP ID" (in the form of a numerical or QR code), which will be engraved or printed on liner within the marking station in the line. Furthermore, customization can be performed at the marking station (marking of the insert with the customer's company logo and name + marking with the order number).

Each CCP ID or product birth certificate contains information about:

- Input raw materials, moisture and batch of material
- CPP extrusion process parameters
- Drying parameter data
- Data on firing parameters
- Data on inspected dimensions + approximate mechanical characteristics predicted by the inspection line
- Information on how to handle the product during its life cycle
- Serial number and date of manufacture

The data in the CPP birth certificate are divided into internal and external, to maintain the internal secrecy of production determining the company's competitive advantage in the market and are also linked to the pallet number on which the CPPs are loaded and packaged.

A unique web form will be created for customer complaints or comments on the delivery, where it will be possible to load the QR code or enter a numeric ID and fill in the complaint form. This ensures feedback between the customer and the company and simplifies the complaint process. At the same time, the company has an effective way of obtaining feedback from customers and the possibility of subsequent stabilization of production.

4. CONCLUSION

This article describes approaches to monitoring and regulating the production of ceramic products, which are based on the principles of Smart Factory and Industry 4.0. The implementation of Industry 4.0 elements for monitoring production in the ceramics industry presents many limitations and differences compared to the automotive industry. Therefore, best practices for implementing new practices and technologies cannot be used. However, the introduction of these elements in the ceramics industry offers, in addition to challenges, new possibilities, such as the introduction of a product birth certificate (ID) and thus detailed monitoring of the product life cycle. It is thus possible to trace back the parameters of production after years of product production or, for example, to react flexibly to changes in output quality by changing production parameters and then guarantee greater quality and stability of production.

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