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PREFACE

The main objective of the *Advanced Logistic Systems* journal is to present research papers related to the material handling and logistics. During the last decade, more than 200 papers were published in the journal, which show that we try to observe and follow the actual state and tendencies of logistic research.

Beside the international research results, the journal gives place for high level national research activities and especially for the work of the University of Miskolc.

During the last three years, the Institute of Logistics of the University of Miskolc coordinated a H2020 project, called UMi-TWINN (No 691942), which targeted to increase the scientific excellence of the University in logistic research. Using the experiences of the high level scientific project partners (the Institute of Engineering Logistics of the Technical University of Graz and the Fraunhofer Institute for Factory Operation and Automation in Magdeburg), the staff of the Institute of Logistics gained much knowledge about their research experiences and results.

In this issue, we publish two papers about the research activities and results of project UMi-TWINN to present the activities performed during the project duration.

Of course, the main objective of this issue does not changed, so other papers present new researches and results related to the logistics, to contribute to the development of the logistics sciences.

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Head of the Editorial Board

Miskolc, 10th December 2018

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MATERIAL HANDLING MACHINES AND SYSTEMS – UMI-TWINN PROJECT CONTRIBUTION

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Abstract: Nowadays, the Industry 4.0 concept affects every area of the industrial, economic, social and personal sectors. The most significant changings are the automation and the digitalization. This is also true for the material handling processes, where the handling systems use more and more automated machines; planning, operation and optimization of different logistic processes are based on many digital data collected from the material flow process. However, new methods and devices require new solutions which define new research directions. In this paper we describe the state of the art of the material handling researches and draw the role of the UMi-TWINN partner institutes in these fields. As a result of this H2020 EU project, scientific excellence of the University of Miskolc can be increased and new research activities will be started.

Keywords: *Industry 4.0, material handling, UMi-TWINN, research cooperation*

1. INTRODUCTION

The world is changing continuously. Nowadays, the Industry 4.0 concept affects every area of the industrial, economic, social and personal sectors. The most significant changings are the automation and the digitalization. Automation means the increasing of the number of self-operated machines and other equipment, digitalization results the application of digital technologies which generate, collect, store and process data during their operation. The spreading of these new elements transforms all sectors of the economic and social life.

This is also true for the material handling processes. Handling systems use more and more automated machines; planning, operation and optimization of different logistic processes are based on many digital data collected from the material flow process. However, new methods and devices require new solutions which define new research directions. In this paper we describe the state of the art of the material handling researches and draw the role of the UMi-TWINN partner institutes in these fields. Main objective of this publication is to outline the research topics and their results related to the project UMi-TWINN and place them into the advanced industrial processes.

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2. RESEARCHES RELATED TO MATERIAL HANDLINGS – STATE OF THE ART

The origins of the material handling disappear in the mist of the past. The simplest solutions to move and lift things and goods were applied in the earlier history of the mankind. Many inventions and ideas were used for different purposes, from the wheel to the sailing ships, to help moving of heavy and large objects.

The first big change in the history of the material handling was the first industrial revolution in the 18^{th} century, in which the motorized machines were appeared and spread. The next step was the starting of mass production in the beginning of the 20^{th} century, where the effective handling became the most important objective.

At the end of the 20^{th} century the material handling was separated into different, specialized groups which have different and limited scope. Of course, the tasks and researches related to these individual categories have different forms and fields, which can help to optimize the methods and devices of the separated areas. In the aspect of researches related to material handling, we can describe 6 main areas *(Figure 1)*:

- structure and operation of the machines,
- system building/complexity,
- planning methods for material handling,
- automated operation,
- operation problems,
- looking for new/special/additional elements/solutions, etc.

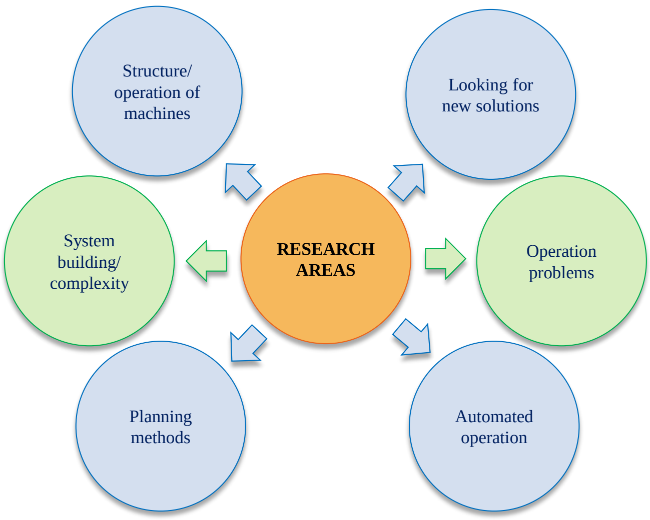

Figure 1. Main research areas of material handling

The oldest research task of material handling is the analysis of the structure and elements of machines. All of the nowadays used handling machines were developed as a result of these researches, but the importance of this activity has been changed for today. Most of material handling machines reached a high level in operation, where the applied materials, elements, structural solutions are near the actual optimum. It means that it is hard to increase the efficiency of the machines. Of course, there are many researches related to the machine elements, but it is realized by the large production companies as an internal research which is not open for the public, or dealing with some special aspects (e. g. [1], [2]).

One of the most frequent research areas is the system building, which is required by all companies using handling machines. Most of the handling tasks are realized by several machines and linked to each other, so the operation of the individual machines requires a system concept. A handling system differs from the simple using of individual machines, because system concept changes the planning and operation environment and the considered conditions which require the application of different methods and devices [3]. System building is a very important and relevant research task in effective production procedures, but it is focusing mainly to the harmonization and connection of handling machines and tasks. A new direction of this area is the complexity analysis of handling systems, which can help to build better system variations and structures [4].

During the planning procedure of material handling, handling tasks among the production or other system objects, related to materials, elements, semi-finished and finished products, have to be solved [5]. In generally this is a very complex task, because of the large number of system objects and handling tasks. Researches related to this field deal with the planning methods and their realization processes [6]. Because of the large differences among the material handling system variations and the complexity of the handling tasks, there is no universal solution for planning of material handling processes, so the research targets to develop new methods and solutions for the planning tasks (e. g. [7]).

Main direction of the industrial area at this moment is the automation of the machines and processes. This tendency is naturally valid for the material handling solutions, where the application of self-operated machines and automated handling processes are in the main focus. Most of the researches related to the automation deal with the operation character of the machines and the elements of data handling required by the automated operation. New directions of these researches are the cooperative robots [8] and the fully automated handling processes [9].

Problems in materials handling are usually related to the dynamic behaviour of the handling machines and the stochastic process or system parameters [6]. It is hard to influence the stochastic events, however the dynamic behaviour depends on the operation characteristics of the machines, which can be influenced. Researches related to the operation characteristics of handling machines try to determine the behaviour of the machine and the influencing parameters to control the dynamic effects (e. g. [10]).

Changing of production processes and customer needs influences the structure and operation of the handling machines, which requires the application of new solutions. Another important part of the researches in material handling is the searching of new elements or solutions for the handling machines, and modify their operation suited to the new needs. This is a very special area, which uses traditional element design methods and also high creativity to develop new solutions (e. g. [11]).

Our scope is the research for handling machines, but there are many research areas, where the activities related also to the logistic systems, because the behaviour of the machines and the handling solutions influences the efficiency of the logistic processes (e. g. [12]). There are many topics, activities and results related to all research fields, but the aim of this paper to show only the researches of the UMi-TWINN project partners.

3. Research activities of the UMi-TWINN partner institutes

In 2016 a new H2020 project have been started (UMi-TWINN), which targeted, among others, to increase the scientific excellence and research capability of the University of Miskolc in the field of logistics. During the project duration, main activity was the knowledge exchange among the scientific project partners, which are the Fraunhofer Institute for Factory Operation and Automation (IFF), the Institute of Engineering Logistics of TU Graz (ITL) and the Institute of Logistics of the University of Miskolc (LOG) [13].

3.1. Fraunhofer IFF

Founded in 1949, Fraunhofer undertakes applied research that drives economic development and serves the wider benefit of society. At present, the Fraunhofer Foundation maintains 67 institutes and research units, the majority of the more than 23,000 staff are qualified scientists and engineers. International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development. With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer Foundation plays a prominent role in the German and European innovation process *(Figure 2)* [14].

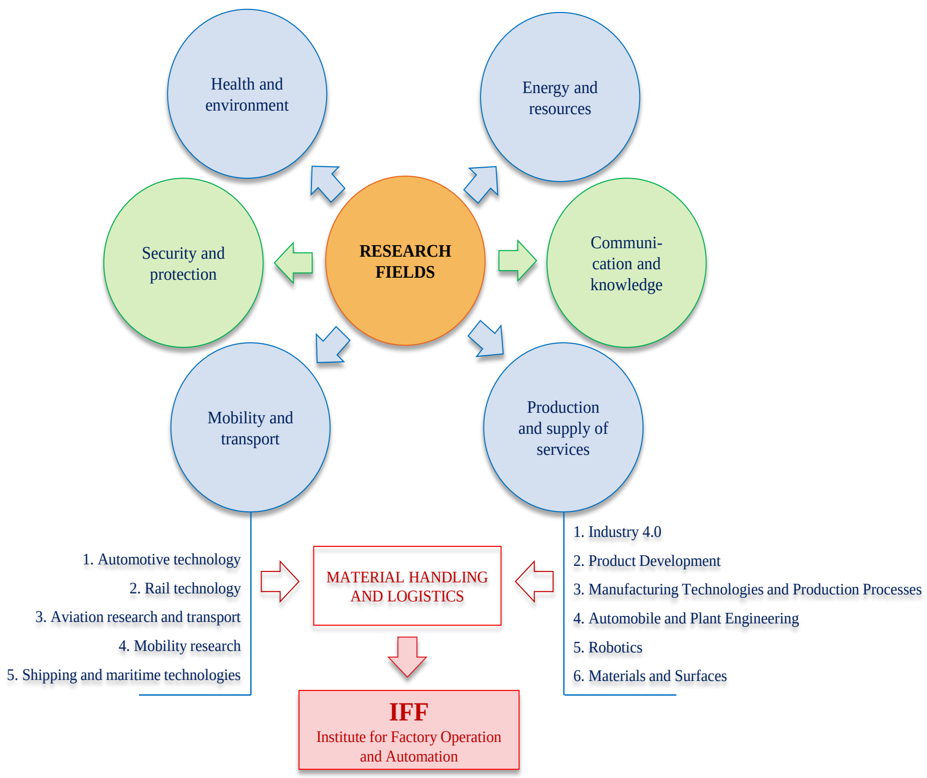

Figure 2. Role of IFF in the research activities of the Fraunhofer Foundation

The Fraunhofer Institute for Factory Operation and Automation is an independent research institute geared toward production engineering in the Fraunhofer Foundation. IFF concentrates its research on factory planning, operation and automation and attaches great importance to new methods and technologies of digital engineering and their extensive use in the development, production and operation of products and manufacturing systems. Main research fields of IFF at this moment [15]:

- smart work systems,
- resource efficient production and logistics,
- convergent supply infrastructures, etc.

3.2. Institute of Engineering Logistics (ITL)

Graz University of Technology pursues top teaching and research in the fields of science and engineering for more than 200 years. An integral part of putting together excellent education and training programs is knowing about the needs of society and the economy. Ultimately, the quality of the education and training at Graz University of Technology is carried by the strength of its knowledge-oriented and applied research. Numerous competence centres, the Christian-Doppler laboratories, special research fields, research focuses, and large EU projects are only a few examples of the university’s extremely active and successful research [16].

As the TU Graz has 7 different faculties, its research activities cover many fields of the economy *(Figure 3)*. Researches related to material handling and logistics belongs to the Institute of Engineering Logistics.

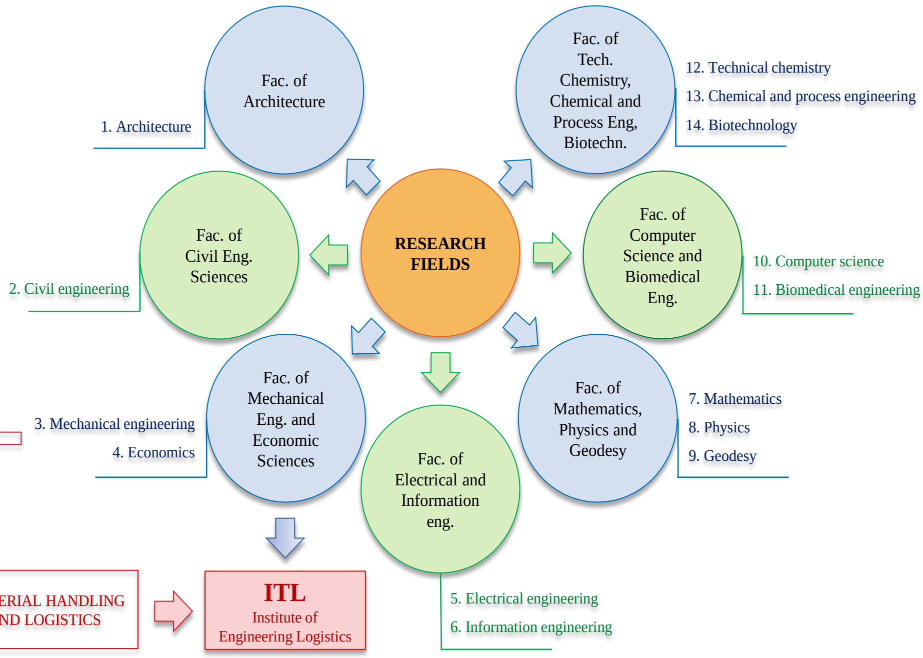

Figure 3. Role of ITL in the research activities of the TU Graz

ITL focuses on the classic problems of logistics planning for the intra- and distribution logistics and the associated layouting and engineering design of logistic systems. In addition to the expertise in planning tasks, the institute was able to expand its expertise in several national and international projects. Research activities and topics are related to the next main areas [17]:

- logistics technologies,
- intra-logistics solutions,
- City-logistics etc.

3.3. Institute of Logistics (LOG)

University of Miskolc is the third largest institution of higher education in Hungary. As a result of the consistent development policy of its 260 year old history, UMi has about 11,000 students and almost 1,200 employees including 720 researchers. Since its foundation in 1949, the Faculty of Mechanical Engineering and Informatics has become an educational and research institution of decisive importance in Hungary [18].

University of Miskolc has 7 different faculties and a music institute, so its education is very colourful. Industrial research activities are belongs to the three technical faculties and the Faculty of Economics *(Figure 4)*. Researches on the field of material handling and logistics related to the Institute of Logistics of the Faculty of Mechanical Engineering and Informatics.

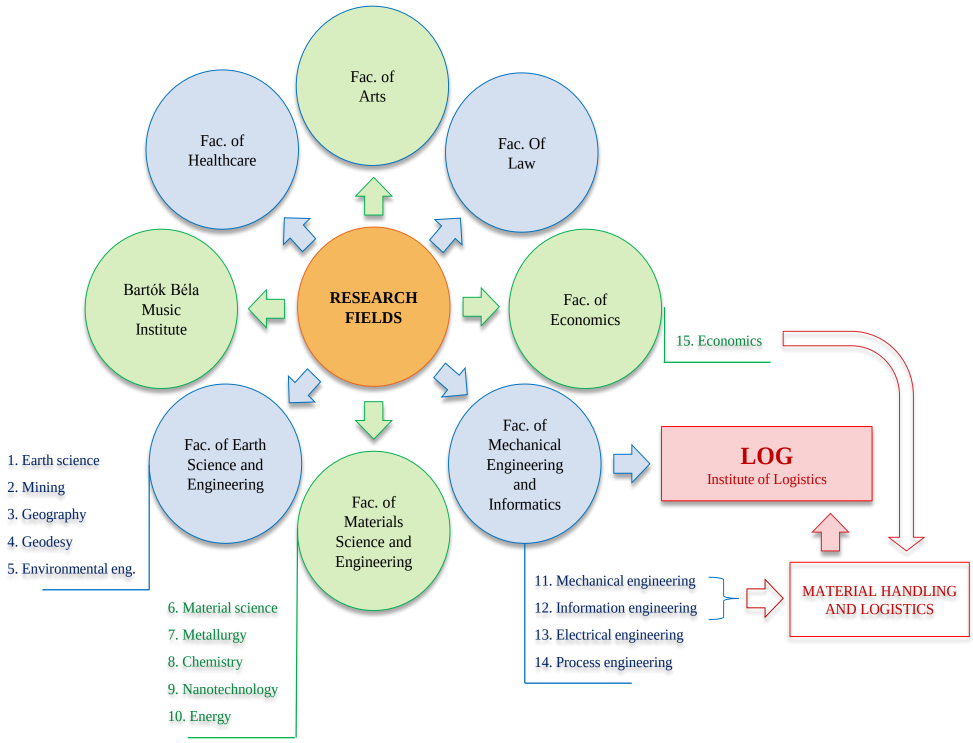

Figure 4. Role of LOG in the industrial research activities of the University of Miskolc

LOG has more than 60 years experiences in research and education, in which numerous national and international, industrial and service, materials handlings and logistics tasks and problems were successfully solved. Unfortunately, the economic changes of the last decades reduced the research works at the Institute in number and also in complexity. Because of this situation, research activities focussed on certain problems and tasks which limited the development possibilities of the researchers. Most of the research and development tasks of LOG related to the handling processes of manufacturing procedures [19]. Relevant research topics of LOG today are

- material handling machines and storage systems,
- handling systems of production processes,
- logistic systems, etc.

4. Researches in project UMi-TWINN

During the preparation of the project UMi-TWINN, we tried to find research directions suited to the profiles of the two, high level scientific partners, and for the start of the project we selected three different, relevant topics which are much important for the economy today (see *Figure 5*).

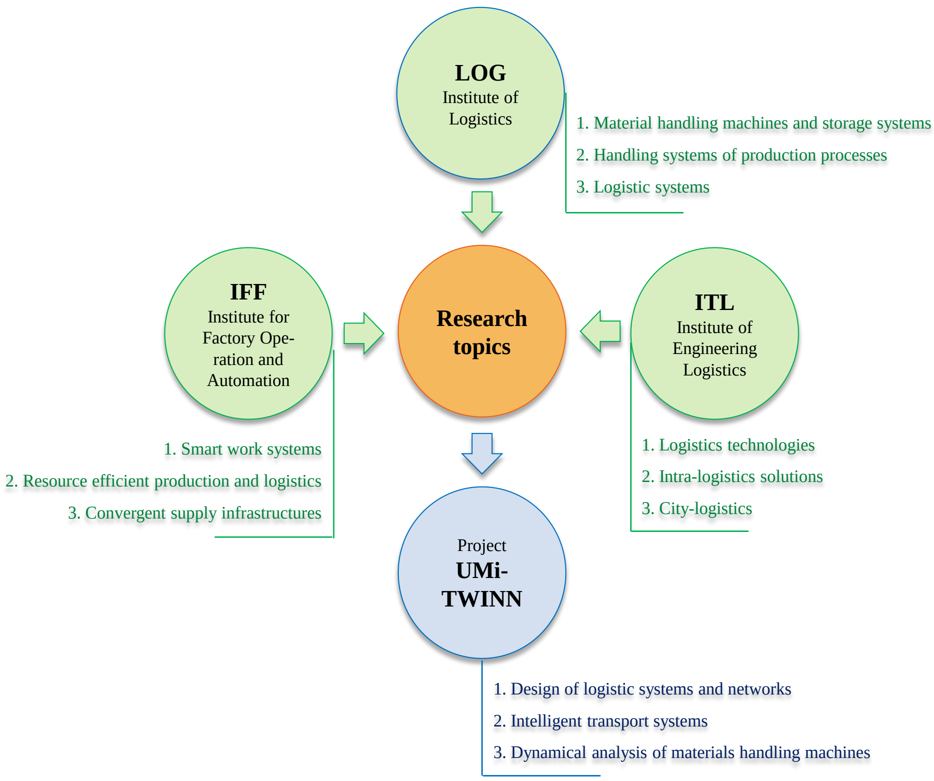

Figure 5. Topic searching for the project UMi-TWINN

Related to the three main directions, we described three exact topics as main research areas for exchange:

1. Design of logistic systems and networks
2. Intelligent transport systems
3. Dynamical analysis of materials handling machines

The topic *Design of logistic systems and networks* (e. g. [20]) focuses on both production and service companies, and includes a wide set of tools and methods related to the supply chain process, such as

- modelling and mathematical description of systems and processes of material handling and logistics,
- development of new equipment selection methods for production systems,
- meta-heuristic optimisation of large scaled networking systems and supply chains,
- design and operation of warehouses and storage systems,
- computer-aided simulation, scenario analysis of production and service process, etc.

The topic *Intelligent transport systems* (e. g. [21]) plays a crucial role in the implementation of different logistics processes. Therefore, the development of a proper network infrastructure is necessary for the unified market of the European Union. Intelligent transport systems and their elements provide the basis for continuously satisfying the quantitative and qualitative needs of the customers involving:

- physical internet,
- engineering methods for better design of material handling equipment in transport systems,
- handle all the transport related information just-in-time,
- selection of the optimal transport parameters through the implementation of various transportation strategies,
- reaching sustainable operation by increasing the energy efficiency, etc.

The topic *Dynamical analysis of materials handling machines* (e. g. [22]) focuses on the planning and operation of handling equipment, and includes:

- planning methods for material handling,
- determination of system parameters,
- analysis of operation parameters,
- analysis of handling processes,
- analysis of dynamical parameters of handling machines, etc.

During the project duration the cooperation realized in different forms, the most frequent activities were the organization of trainings, personal consultations with researchers, participations on international conferences, publications in international journals and preparation of joint papers and presentations.

As there are different subtopics belongs to all three directions, researchers involved into the project dealt with many different problems *(Figure 6)* and resulted trainings, journal papers and conference presentations. Some of the research topics have relations to more than one project fields.

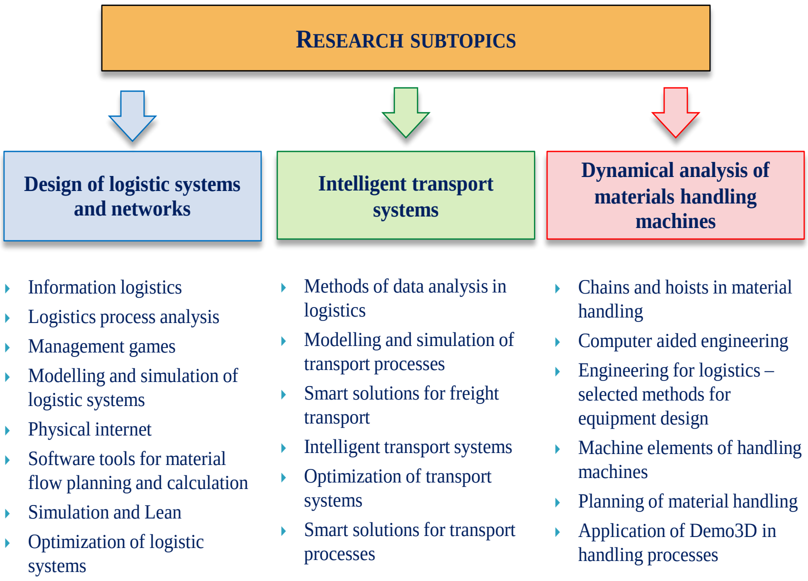

Figure 6. Topics trained and published in UMi-TWINN

Our paper deals only the activities related to material handling, so we will give overview about these publications and results. Activities related to material handling were realized in four main subtopics:

- operation and problems of handling machines,
- design of handling machines and systems,
- determination of handling parameters,
- advanced solutions for handling machines.

4.1. Operation and problems of handling machines

Analysis of the operation of handling equipment is a general research task, but because of the large deviations among the different machine types, it is hard to use a general method for this purpose. In project UMi-TWINN we dealt with only certain machines, which suited to the experiences of the partner institutes. During the project duration there were 3 trainings (by staff of ITL) on the specifications of machine elements of handling equipment (e. g. chains). In this topic, staff of LOG and ITL published 3 papers in conference books [23], [24] and an international journal [25]. Important part of the knowledge exchange was the dynamical behaviour of chain elements in handling machines *(Figure 7)*.

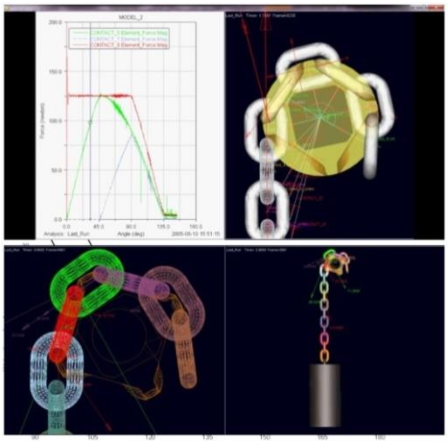

Figure 7. Analysis of chain elements in hoist
source: ITL

4.2. Design of handling machines and systems

Design of material handling machines and systems is a very old research topic, but there is no universal method so far. In project UMi-TWINN we had 2 main objectives in this matter, summarizing and evaluating the existing methods and trying to develop new planning processes. During the project duration there were 2 trainings on the project workshops (by staff of LOG) about the applied methods and a new planning concept (process-based planning). In this topic, staff of LOG and ITL published 5 papers in a conference book [26], [27] and in international journals [28], [29], [30]. Most important results of the knowledge exchange in this topic is the implementation of KBE concept into the research and education of LOG and the development of the process-based planning concept *(Figure 8)*.

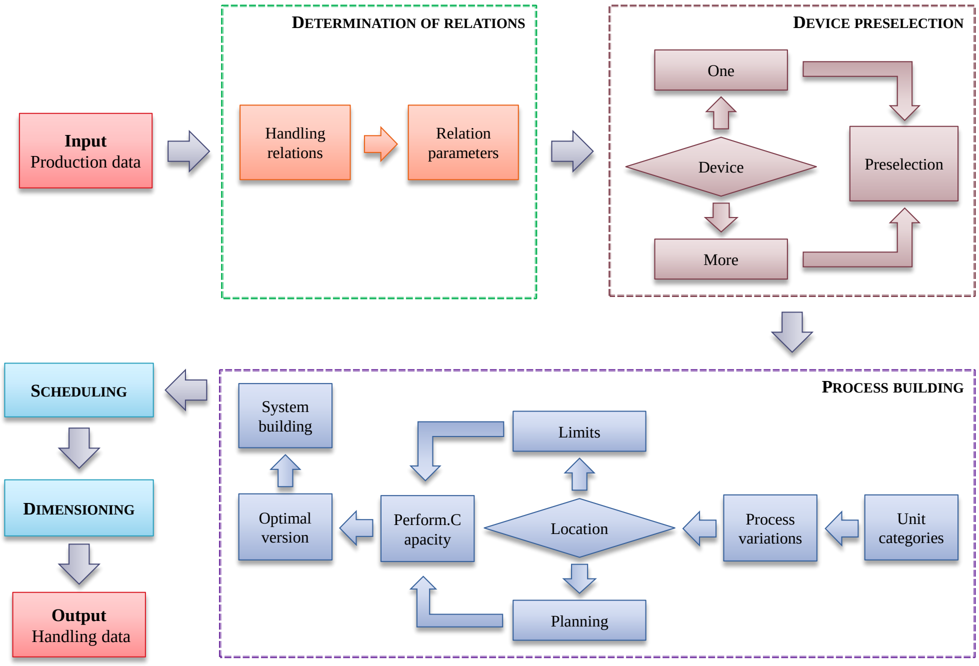

Figure 8. Algorithm of the process-based planning [29]

4.3. Determination of handling parameters

Planning and operation of handling equipment is based on the handling parameters, but in many of the cases they are not previously given so they have to be determined. In project UMi-TWINN we targeted to describe methods for the easy and exact calculation of the handling parameters. During the project duration there were 2 trainings (by staff of IFF and ITL) on the calculation methods and application of handling parameters and some computer devices for them. In this topic, staff of LOG published 5 papers in a conference book [31] and in international journals [32], [33], [34], [35]. Most important result of the knowledge exchange is computer software (MHRelCalc) for the calculation of handling relations *(Figure 9)*.

Figure 9. Screenshot from the software MHRelCalc [31]

4.4. Advanced solutions for handling machines

Suited to the Industry 4.0 concept, material handling methods and devices have to be adapted to the new challenges, which requires many new solutions and additional elements. In project UMi-TWINN we tried to search relevant fields on which the experiences of the partner institutes can be implemented into the practice of LOG and the advanced solutions have to be further developed. During the project duration there were 3 trainings (by staff of IFF and ITL) on advanced devices and solutions (e. g. planning software). In this topic, staff of LOG, IFF and ITL published 5 papers in a conference book [36] and international journals [37], [38], [39], [40], [41]. Significant parts of the knowledge exchange were the automation in material handling and the application of artificial intelligence (AI) in handling devices *(Figure 10).*

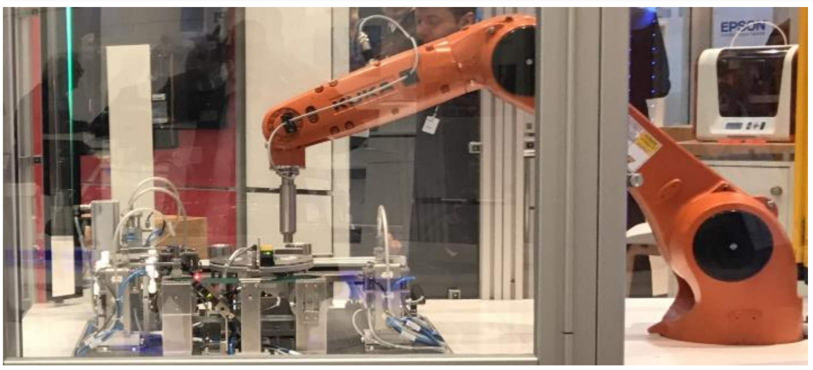

Figure 10. Virtual Numerical Control Environment VINCENT
source: Fraunhofer IFF

5. SUMMARY

Handling systems use more and more automated machines; planning, operation and optimization of different logistic processes are based on many digital data collected from the material flow process. However, new methods and devices require new solutions which define new research directions. Researches related to material handling are important factors to build effective, high performance handling processes for advanced manufacturing systems.

In this paper we gave an overview about the researches related to material handling involved into the project UMi-TWINN, and their significance in the industrial processes. During the UMi-TWINN project duration, staff of the partner institutes presented 6 research topics on international conferences all over the world and 12 papers were published in international journals related to material handling.

As a result of these research activities new research directions were defined which are important not only for the University of Miskolc, but his scientific project partners.

Most important output of these activities is the scientific reinforcing of the Institute of Logistics of the University of Miskolc. All research topics exchanged during the project are relevant industrial topics, which requires advanced technical solutions and high level knowledge in the related fields.

We hope that after the closing of project UMi-TWINN, we can continue the cooperation among the partner institutes and we can implement the gained knowledge and devices into the educational and research activities of the University of Miskolc.

At the other hand, based on the exchanged knowledge, the staff of LOG will continue the started researches and can add new values to the performance and quality of the industrial handling processes.

ACKNOWLEDGEMENTS

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COOPERATION IN LOGISTICS TECHNOLOGY RESEARCH: HOW TWINNING PROJECT AFFECTS R+D IN THE FIELD OF LOGISTIC SYSTEMS AND NETWORKS

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Abstract: The overall aim of the UMi-TWINN project was to reinforce the scientific excellence and innovation capacity in logistic systems of the University of Miskolc and its high-quality twinning partners for the benefit of different industries and logistics markets. To boost twinning partners' scientific excellence and innovation capacity in logistics technologies, as well as implementing a research and innovation strategy we have focused on the following three sub-topics: design of logistic systems and networks, intelligent transport systems and dynamical analysis of materials handling machines. Within the frame of this paper the authors describe the main results in the field of design of logistic systems.

Keywords: *complexity, heuristics, Industry 4.0, last mile logistics, optimization, staff deployment, supply chain design*

1. INTRODUCTION

The UMi-TWINN project is funded under the "Spreading Excellence and Widening" section of the Horizon 2020 Programme [1]. The Twinning scheme aims to strengthen a defined field of research in a knowledge institution through linking with internationally-leading counterparts in Europe. The UMi-TWINN project is focusing on logistics technologies at the University of Miskolc (Hungary). The consortium partners have three years to achieve the following objectives: strengthen UMi's research excellence in logistics technologies; enhance the research and innovation capacity of UMi and Twinning partners; raise the research profile of UMi and the Twinning Partners; contribute to the research and innovation priorities of Hungary; support research and innovation on a European level.

The research and innovation strategy takes the recent SWOT analysis of UMi as well as the national Hungarian research priorities and regional Smart Specialisation Strategy

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'Advanced technologies in the vehicle and other machine industries' as well as the SMART technologies relevant to the Borsod-Abaúj-Zemplén county (e. g. 'Logistics' and 'Special materials, advanced materials, modern materials technologies') into account. The overall concept of the UMi-TWINN project and the position of design of logistic systems and networks topic is shown in *Figure 1*.

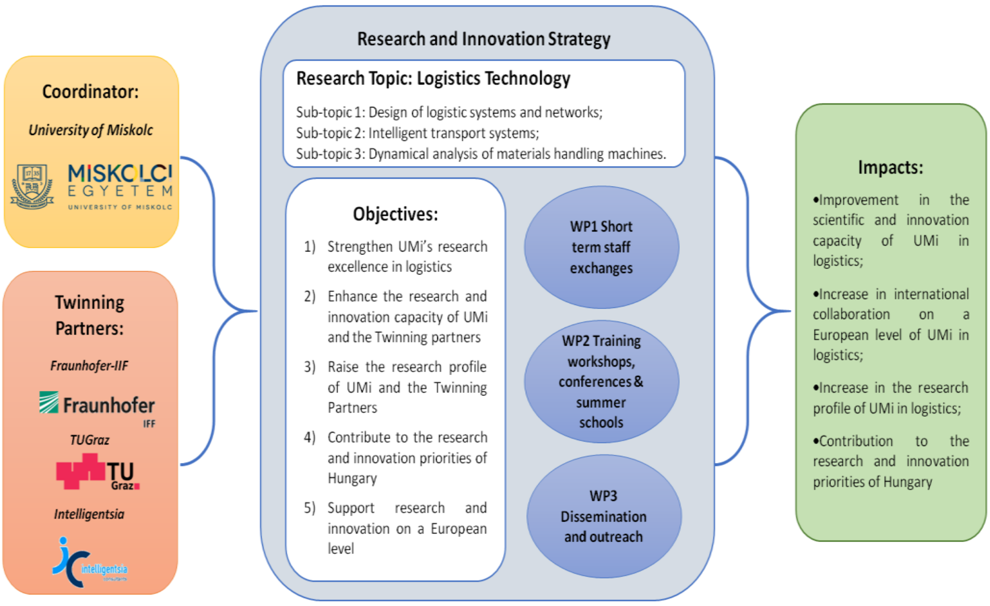

Figure 1. The overall concept of the UMi-TWINN project

2. Economical Background

The European logistics sector has recovered from the effect of the crisis in 2008/09 and the Eurozone economy grew 0.2 percent on quarter in the three months to September 2018, unrevised from a second estimate and following a 0.4 percent expansion in the previous period [2] supported by the manufacturing sector. New retail trends (e. g. e-commerce) are an increasingly important driver of change in the logistics sector. According to forecasts from Forrester Research, European online retail sales will increase at an average of 11.5% per year from 2018 to 2023. The European sector is also experiencing a continuing shift in activity towards the east, as logistics operators seek to build efficient distribution networks. Hungary benefits from its location in the centre of Europe and has potential to become a major European hub at the crossroad between Western and Eastern Europe, but also close to the Mediterranean region.

The aim of UMi-TWINN is to adapt, develop and integrate logistics technologies into new tailor made manufacturing in order to be used by the industry and especially small to medium-sized companies (SMEs). From that perspective the UMi-TWINN project will support UMi's research building capacity and promote its research excellence in logistics sciences and technology in Hungary but also in Europe.

The project and the design of logistics systems and networks topic contributed to the research and innovation priorities of Hungary. Hungary has defined their SMART specialisation strategy for the country and regions/counties. The Eye@RIS3 tool [3] available on the S3 platform defined the national priorities among them of the SMART Specialisation Strategy 'Smart Technologies'. The Hungarian Development and Innovation Office defined the priorities per county within a report highlighting the importance of 'Logistics' and 'Special materials, advanced materials, modern materials technologies' R&D for the Borsod-Abaúj-Zemplén county. Nevertheless the UMi-TWINN project contributed to most of the national SMART technologies listed in the report based on its three research sub-topics *(*see *Figure 2)*.

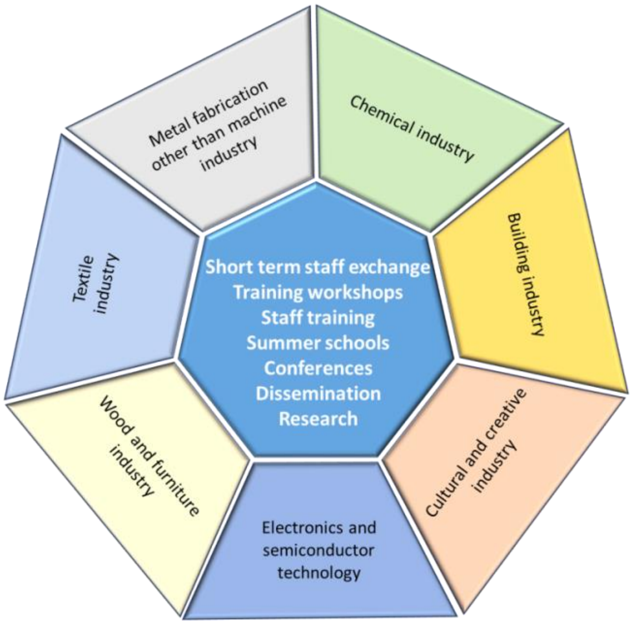

Figure 2. National SMART technologies and project activities

In Q1 2018 the volume of Hungary's GDP was up by 4.4 percent year-on-year. Seasonally and calendar-effect adjusted and reconciled data show that economic performance improved by 4.7 percent year-on-year and by 1.2 percent quarter-on-quarter. Market-based services were the main driving force behind the expansion [4]. Logistics technologies contribute to this growth and open new opportunities for the Hungarian and European economy. The UMi-TWINN impacts directly or indirectly the main national industries. The share of the business sector in the sources of R&D expenditures reached 56% or €777m, of the government sector 26% or €361m, while the foreign sources achieved 16% or €229m in 2016. The share of the domestic non-profit sector is negligible (0.7%). From the perspective of Hungary's society and economy, there are at least three groups of organisations that benefit from the UMi-TWINN project:

- **Automotive companies** constantly need to upgrade their production facilities and improve their logistics flow. The automotive industry is one of the main pillars of Hungarian manufacturing.

- **Electronic and mechatronics companies** requiring innovative logistics technology to develop new machine handling and improve the efficiency of their products.
- **Logistics companies** are the main concern by the UMi-TWINN project and benefit from every advancement made on the three research sub-topics.

Within the frame of this paper we are focusing on the research results of the project as follows.

3. RESEARCH RESULTS IN THE FIELD OF LOGISTICS SYSTEMS AND NETWORKS

However the main activities of this Twinning project were focused on mobility (staff exchange), trainings and conferences, but the scientific cooperation was also strengthened. *Figure 3* summarises the main research fields, where the cooperation led to scientific results published in international conferences and scientific journals.

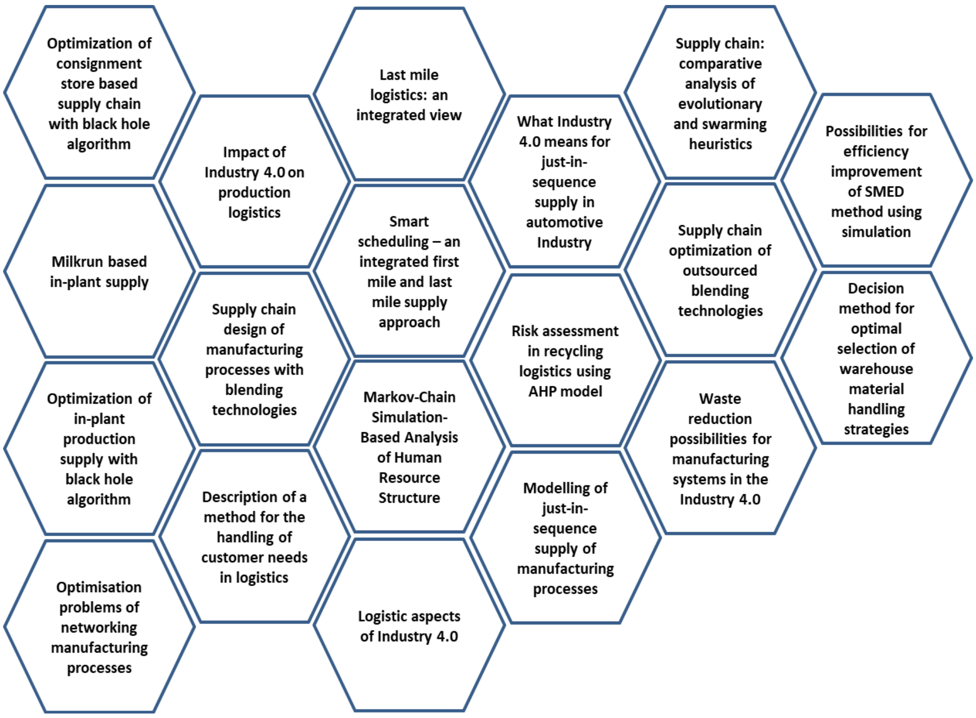

Figure 3. Main research fields related to twinning activities

3.1. Optimization of consignment store based supply chain with black hole algorithm

Within the frame of this research work we developed a methodological approach for design of consignment store based supply chains. Firstly we reviewed and systematically categorized the recent works presented for consignment store based supply chain optimization. Then, motivated from the gaps in the literature, a model for companies performing their purchasing through consignment stores was developed. Two models were proposed: the model framework shows the levels of supply chain while the second model as a case study focused on power plant supply. The integrated model included facility location and assignment problems, which was solved with black hole optimization algorithm. The sensitivity analysis showed the efficiency of two advanced BHO operators and a numerical example shows the efficiency of the algorithm.

The scientific contributions of this research work were the followings: integrated model for consignment store based supply chain, black hole optimization based heuristic algorithm with enhanced convergence through integration of phenomena of real black holes, like dynamic black hole location and decreased event horizon. The results can be generalized, because the model can be applied for in-plant supply, especially in the case of milk-run based just-in-sequence supply. The described methods make it possible to support managerial decisions; the operation strategy of the supply chain and the consignment contract can be influenced by the results of the above described contribution.

However, there are also directions for further research. First, although the transportation routes as distances among the locations are considered, the capacities of vehicles are not taken into consideration. In further studies, the model can be extended to a more complex model including capacities of vehicles and store capacities of locations. Second, this study only considered the black hole optimization method as possible solution algorithm for the described NP-hard problem. In reality, other heuristic methods can be also suitable for the solution of the problem.

Third, the convergence of the described algorithm can be improved using other operators and the behaviours of BHO to other optimization approaches can be tested. However there is a great body of research dealing with testing of performance of different metaheuristic optimization methods, especially from the point of view "novel" algorithm, but these tests are sometimes inconsistent. This inconsistency can be caused by the optimization behaviour [5].

3.2. Smart scheduling – an integrated first mile and last mile (FMLM) supply approach

Industry 4.0 solutions make it possible to improve traditional supply chain solution in hyperconnected logistics systems. Within the frame of this common research work we developed a methodological approach for real-time smart scheduling of first mile last mile delivery of cooperating delivery companies. Firstly we review and systematically categorized the recent works presented for the design of FMLM supply. Then, motivated from the gaps in the literature, a model for cooperating FMLM supply is developed. We proposed a general model. The described model includes different delivery routes of different companies, where the cooperation is based on Industry 4.0 solution including vehicle re-identification, GPS based methods and smartphone-based monitoring. The smart scheduling means the real-time optimization of assignment of open tasks to the scheduled routes depending on the captured information from the running processes. The smart scheduling problem was solved with a newly developed metaheuristic combining BHO (black hole optimization) and BBBC (big bang big crunch) algorithm. The sensitivity analysis showed the efficiency of the integration of both swarming heuristics.

The scientific contributions of this paper are the followings: model for the integrated real-time scheduling of first mile and last mile operations in a package delivery environment, where the hyperconnected operation is based on Industry 4.0 solutions; a new metaheuristic combining the Black Hole Optimization and the Big bang Big Crunch Algorithm. The results can be generalized, because the model can be applied to different supply chain applications, especially in the case of a multitier supply chain for the automotive industry. The described methods make it possible to support managerial decisions; the operation strategy of the package delivery companies and the cooperation contract among them can be influenced by the results of the above-described contribution [6].

3.3. Impact of Industry 4.0 on production logistics

The factory of the future is flexible and transparent. This means that the time of workflows, preparations and switching times can be accurately calculated, so you can determine where there are free capacities. This way, when you receive a customer order, you can accurately calculate when the order is being made and what capacities, machines, tools will be assigned, and what purchases will have to take place until the start of production.

Within the frame of this research we reviewed the technological background and main features of the fourth industrial revolution. We analysed the competitive advantages achieved through the vertical network of intelligent manufacturing systems and horizontal integration, demonstrated the properties of the smart cell, and determined the levels of services built into the smart product.

Our research work focused on the relationship-system of the company's production logistic system, with logistics-integrated production management tasks and with the competitive advantages. In solving a specific production logistic problem, we have demonstrated the competitive advantages of real-time scheduling. The above-mentioned research has many possible directions for further development, as Industry 4.0 is characterized by multidisciplinary that allows further research not only in technical but also in economic and social fields. In relation to production logistics, our future objectives include further examination of the service processes of complex manufacturing systems, in which we intend to set up in-house supply chains that ensure the efficient management of large complex production processes through integrated management of cooperative tools and sub-processes [7].

3.4. Last mile logistics: an integrated view

The solutions of last mile logistics make it possible to make decisions in supply chain networks aiming financial and environmental effects, and also reduce unnecessary movements of delivery. As the relevant state-of-art showed, significant financial savings are available for participants using the concepts of last mile. This result indicates the scientific potential of this research field including the problems of last mile logistic systems. This research field addressed the manufacturing and service participants to identify the logistic aspects from design and operation point of view of supply chain.

Therefore, the design aspects of supply chain processes still need more attention and research. There are four sub-types of last mile topology: semi-extended supply chain, fully extended supply chain, decoupled supply chain, and centralized extended supply chain *(Table I)*. These topologies were analysed within the frame of this research field [8].

3.5. What Industry 4.0 means for just-in-sequence supply in automotive Industry?

The Industry 4.0 solutions make it possible to develop just-in-sequence supply chain among tiers aiming economic and environmental sustainability and also for capacity use. The featured models make it possible to analyse the just-in-sequence supply chain between tiers. Significant financial savings are available using optimized just-in-sequence solutions.

This study developed a methodological approach for modelling just-in-sequence supply. In this paper, firstly we reviewed and systematically categorized the recent works presented for just-in-sequence supply. Then, motivated from the gaps in the literature, a model structure was developed. Four models were proposed with direct/indirect supply and sequencing, with/without horizontal cooperation [9].

Table I
Component of Last mile typology and their benefits (less important, *** necessary)*

Impacts	Semi-extended supply chain	Fully extended supply chain	Decoupled supply chain	Extended supply chain
Security	**	**	**	***
Inventory	***	***	***	***
Networks	**	***	**	**
SCM	***	***	***	***
Energy	**	***	**	***
Manufacturing	*	*	*	*
Delivery speed	**	**	***	***
Customer satisfaction	**	**	**	***
City logistics	**	**	***	***
Mobility	***	***	***	***

3.6. Supply chain optimization in automotive industry: comparative analysis of evolutionary and swarming heuristics

The automotive industry is one of the world's most significant economically and most dynamically developing industries. In order to compete with each other, they have to come up with new techniques, tools and services. These novelties are based on a well-established information system that supports communication, design, customer service and the company's entire internal system. It controls supply, production, distribution and waste management (see *Figure 4)*. However, this requires a very large amount of data that needs to be elaborated and categorized so these solutions can be made to make things much more comfortable and accessible to us and we can easily intervene [10].

However, to accomplish these, very good and fast IT tools are needed, that are driven by algorithms. The algorithm we used for different tasks greatly influences the quality of the solution obtained and the speed of its calculation. In most of today's IT systems one of the variants of the genetic algorithm can be found. Within the frame of this common research work, we have sought to find out whether there is an algorithm that is faster and more reliable than this already proven and widely spread algorithm. Comparing the performance results with the Black hole algorithm in function analysis and warehouse positioning problem, we came to the conclusion that this recently presented algorithm can overcome the genetic algorithm both in speed and accuracy.

3.7. Milkrun based in-plant supply – an automotive approach

Within the frame of this research field we developed a methodological approach for the description and analysis of milkrun based in-plant supply. We reviewed and systematically categorized the recent works presented for milkrun supply. Then, motivated from the gaps in the literature, the morphology and three typical milkrun processes were described. The described supply systems were analysed from the aspect of cycle time and proportion of operations. The results can be generalized because the model can be applied for a wide range of milkrun strategies. The described methods make it possible to support managerial decisions; the strategy of resource management can be influenced by the results of the above described contribution [11].

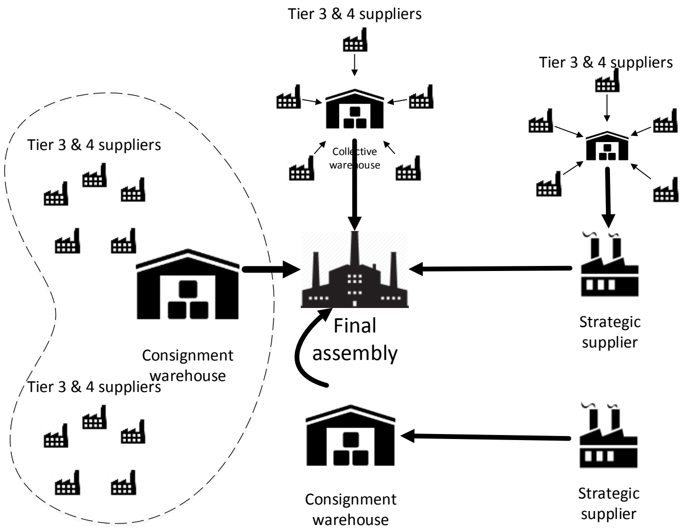

Figure 4. Model of warehousing in a supply chain

3.8. Supply chain design of manufacturing processes with blending technologies

Blending technologies play an important role in manufacturing. The design and operation of manufacturing processes using blending technologies represent a special range of manufacturing related logistics because the integrated approach of technological and logistic parameters is very significant. This research proposes an integrated model of supply of manufacturing processes using blending technologies. After a careful literature review, we introduced a mathematical model to formulate the problem of supply chain design for blending technologies. The integrated model includes the optimal purchasing strategy depending on the characteristics of components to be mixed in the desired proportion and the costs of supply. The integrated model is described as a linear programming problem. Numerical results with different datasets demonstrated how the proposed model takes technological and logistic aspects into consideration [12].

3.9. Optimization of in-plant production supply with black hole algorithm

Logistic processes are basic factors in the success of manufacturing plants' operation and have direct impact on its efficiency, flexibility and reliability. Today's successful operation of manufacturing processes addresses high priority to logistics to ensure maximum utilization of resources. The material supply of manufacturing processes in the automotive industry is usually based on supermarkets and milkruns. This research focused on the integrated supply model of manufacturing processes, which includes facility location and assignment. After a careful literature review, we introduced a mathematical model to formulate the problem of supermarkets and milkrun based supply of machines. The model seeks the optimal location of buffers as well as the optimal assignment of buffers and machines so as to minimize the material handling costs while taking into account order limits of machines and capacities of resources. Next, we demonstrated an enhanced black hole algorithm dealing with multi-objective supply chain model to find the optimal structure of the system. Numerical results demonstrated how the proposed model supports the efficiency, flexibility and reliability of the manufacturing process [13].

3.10. Optimisation problems of networking manufacturing processes

Manufacturing systems are more and more complex. Heuristic optimization offers powerful tools and methods to design networking manufacturing systems. Within the frame of this research we described two possible optimization methods of knapsack and traveling salesman problem with harmony search and firefly algorithm to support the optimization of various manufacturing related logistic problems. As a result of the demonstrated research it can be expected that in future years more and more optimization application will be developed in the field of supply chain. The results of this research can be used to improve the whole logistics process of companies *(*see *Figure 5)* from the purchasing through production logistics to distribution [14].

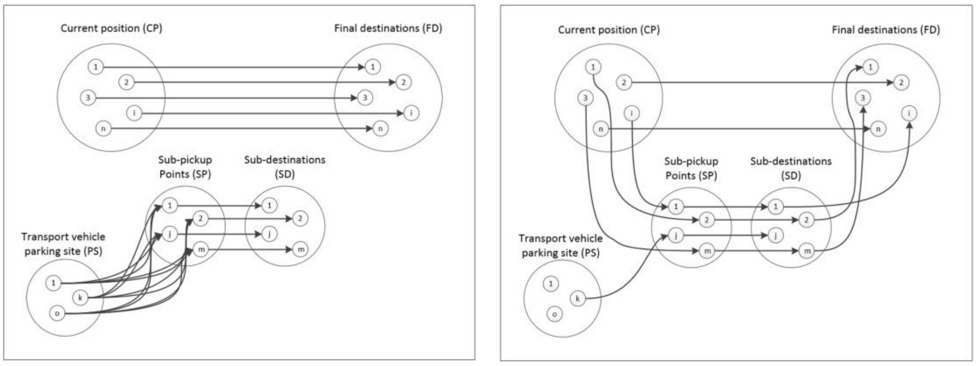

Figure 5. Structure of networking manufacturing processes

3.11. Supply chain optimization of outsourced blending technologies

This research activity of the UMi-TWINN project developed a methodological approach for supply chain optimization of manufacturing companies using blending technologies. Firstly we reviewed and systematically categorized the recent works presented for outsourcing optimization f supply chain. We analysed the selected articles. Then, motivated from the gaps in the literature, a model framework for supply chain including outsourcing possibilities of blending technologies was proposed: the model framework makes it possible to define typical models depending on the problem and complexity of the supply chain. We proposed a mathematical model for the description of a typical supply chain of blending technology based manufacturing including suppliers, manufacturers, outsourcing possibilities and customers *(*see *Figure 6)*. The optimization problem includes three decisions: volume of components to be purchased to blend them in a desired proportion to produce goods in a defined quality;

selection of suppliers and outsourcing allocation. Computational results of the described model were presented with different datasets.

As the results show, outsourcing possibilities are cost-cutting tools for blending technologies, but the parameters of logistics and technology influences the efficiency. The results can be generalized, because the model can be applied for other technologies, especially in the case of assembly sector. The described method makes it possible to support managerial decisions; the operation strategy of the supply chain and the procurement contract can be influenced by the results of the above described contribution.

However, there are also directions for further research. First, although the logistic costs are considered, logistics strategies (e. g. inventory holding or routing) were not taken into consideration. In further studies, the model can be extended to a more complex model including logistic strategies. Second, this research only considered the problem as MILP (mixed integer linear programming) and MINLP (mixed integer nonlinear programming) problems but in the case of increased complexity the problem can be described as an NP-hard problem. Third, the model can be tested with real data sets. This should be also considered in the future research [15].

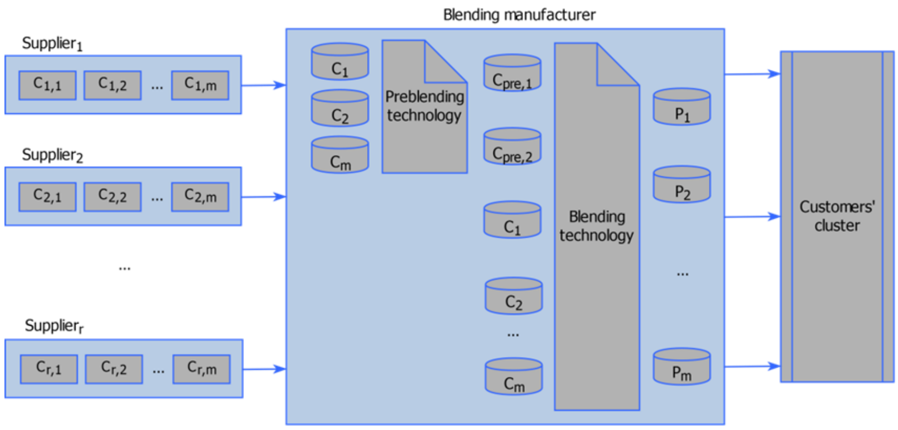

Figure 6. Supply chain of blending technology with multiple suppliers, pre-blending and direct supply

3.12. Logistic aspects of Industry 4.0

Through the fourth industrial revolution, today such technological innovations and methods have become available which enable the development of complex logistics systems where the entire supply chain can be operated in an automated way. The aim of this research field was to investigate how to increase the efficiency of logistics processes through the exploitation of the opportunities offered by the fourth industrial revolution. We summarised the essence of Industry 4.0, the technological conditions of the fourth industrial revolution, its opportunities and challenges, and examines its impact on both intra-corporate and non-corporate logistics processes. We analysed the operational processes of logistics networks and the efficiency gains achieved through Industry 4.0 applications. Reliability and quality assessment of logistics networks are a complex problem. We presented an innovative solution which is based on Industry 4.0 infocommunication solutions and the application of risk management and quality assurance tools, one that enables the optimal selection of logistics service providers in the network from a reliability point of view [16].

3.13. Modelling of just-in-sequence supply of manufacturing processes

Sourcing strategies are very important for a successful supply chain. It is important to understand how just-in-time based sourcing of manufacturing companies works to choose the best solution. Just-in-sequence solutions support the decrease of inventory levels, but the design and operation of these supply processes can be expensive. Within the frame of this research work we described a model framework *(*see *Figure 7)* of just-in-sequence supply and defined the most important JIS based supply strategies: ship-to-sequence, pick-to-sequence and build to sequence [17].

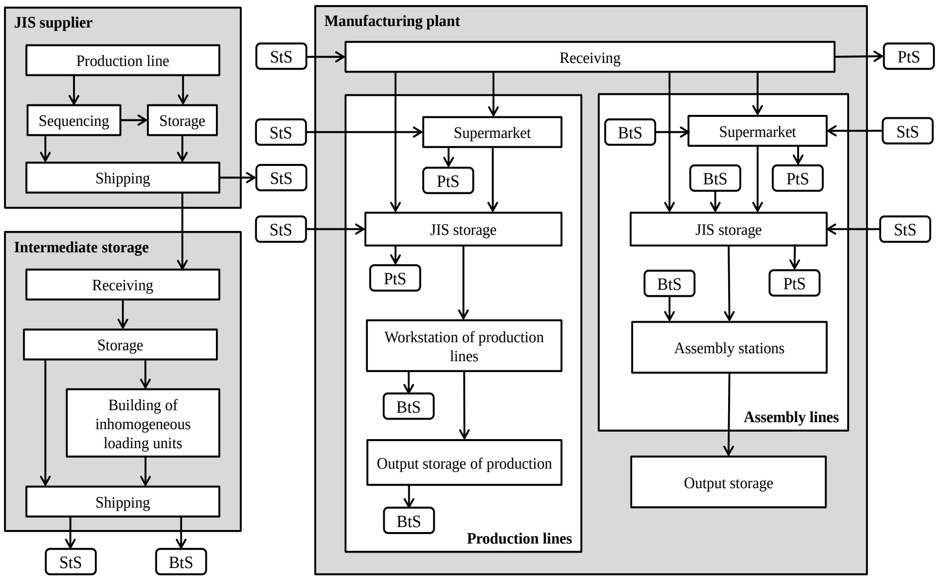

Figure 7. Model framework of just-in-sequence supply including possible relations of pick-to-sequence (PtS), ship-to-sequence (StS) and build-to-sequence (BtS) supply

3.14. Markov-Chain Simulation-Based Analysis of Human Resource Structure

Staff deployment and staffing is an essential problem in the human resource management domain because the structure of employees should be continuously in an optimal relationship to the jobs to be performed. The main focus of this research is the modelling and analysis of human resource deployment processes of manufacturing companies using Markov-chain mathematics, also taking the absorbing phenomena of employees' promotion into account. The main contribution includes the model framework of Markov-chain simulation of a human resource deployment problem; the mathematical description of different human resource deployment strategies with subdiagonal and superdiagonal promotion matrices; the computational results of the described model with different datasets and scenarios. In the case of a given human resource strategy, the Markovian human resource deployment process of a company was analysed *(*see *Figure 8)*. The analyzed model was the HR deployment of assembly line operators in a multinational company, including six levels of promotion [18].

3.15. Risk assessment in recycling logistics using AHP model

The AHP is a widely applied multi-criteria decision making technique that was originally developed by Thomas L. Saaty in the 1970s. Since then, it has become one of the most popular methods with a wide range of applications. The goal of this research field is to examine which criteria affect more the accumulation of the additional risk related costs for the given customer. In other words, the risk factors will eventually be ranked by the amount of additional costs they are generally responsible for at the given customer, determined through the use of the decision hierarchy. In general, the more additional cost a risk factor is responsible for, the higher its priority should be at the end of the analysis.

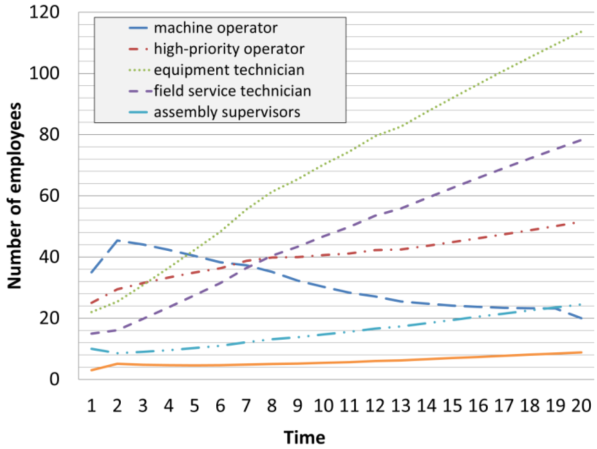

Figure 8. Results of AMC simulation of a Scenario – Distribution of employees through the time window

The proposed decision hierarchy has four levels *(Figure 9)*, where the first node on the first level is the "Risk related cost" (the goal of the analysis), the main criteria level (second level) is composed of the "Inner processes", the "Environment", the "Managed cargo", the "Partners", the "Reputation" and the "Alternative scenarios" nodes, while the third level is constructed from the different sub-criteria related to the main criteria (the fourth level is composed of the decision alternatives, which in this case are the risk factors).

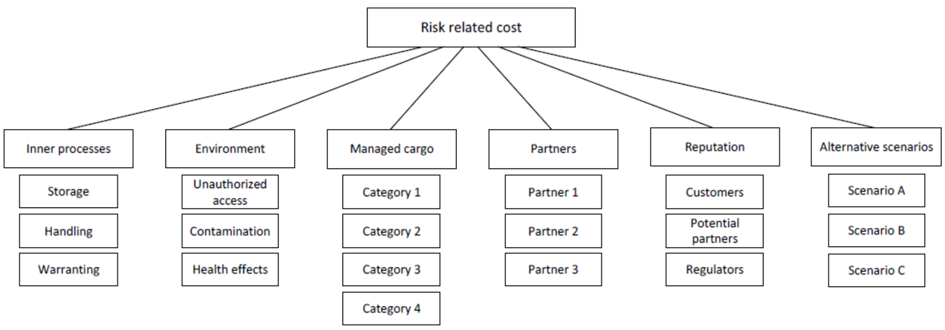

Figure 9. Decision hierarchy of the proposed risk-assessment model

A possible way for the evaluation of the results was also presented, which can be helpful for supporting the selection process of logistics service providers in the aforementioned networks. The longer term intention would be to further develop the concept into a general tool that can be applied in a wide variety of integrated logistics networks. As the core model in the approach is flexible enough for customization, there should be no theoretical barriers to achieve this goal, which would greatly aid the various parties of the modern logistics industry in effective risk assessment and partner selection [19].

3.16. Description of a method for the handling of customer needs in logistics

Logistical problems and tasks arise in all areas of the industry and economics. This puts a lot of requirements on the comprehensive field that is today called as logistics. In the meantime, logistics is under constant change due to the technical innovations and the changing social and political boundary conditions. The diverseness and the system dynamics present a great challenge for the logistics professionals of the future, as intelligent and economical solutions are awaited from them. Within the frame of this research topic, we developed an application of the QFD (quality function deployment) method, a technique used for the evaluation and proper realization of the different customer expectations, in the quality management of logistics systems. Both the theoretical basics of the method, as well as the main steps of its implementation were described. The implementation itself was presented with the help of a practical example that is strongly related to both the logistics and the automotive industries, as the latter especially relies on complex supply chains that require the extensive utilization of quality management tools. Besides the previous, the research also provided an overview of all the possible areas of utilization for the QFD in the logistics industry. Therefore, the developed method can have a great value from both the academic and the industrial perspectives [20].

3.17. Examining the possibilities for efficiency improvement of SMED method using simulation modelling

Nowadays the improvement mode of logistics processes has a relevant effect on an enterprise's competitiveness. Most production companies have three kinds of objectives, namely reduction of the production lead time, cost reduction, and improvement in quality, all of which can be realised by using the tool and rule system of the lean philosophy. To explain the essence of the lean philosophy, it is the reduction of the lead time between the ordering and the payment with elimination of wastes, according to the most popular explanation. The lean philosophy has two "pillars" which are JIT and jidoka. The essence of jidoka is that we have to separate the human and the machine work with "human sensors" (for example: we do not need to supervise a machine if we put a mechanism into the machine which is able to stop the machine in the case of some problem). We can better utilise the human and machine resources using this principle. We can reach significant results in the field of waste reduction in production processes with application of the tool and rule systems of lean philosophy. One of the frequently applied lean methods is SMED (Single Minute Exchange of Die), which is able to reduce the changeover times and the resulting wastes. Length of the changeover time has a relevant effect on several parameters of the production process (inter-operational inventories, batch sizes, production lead time, manufacturing flexibility, etc.), consequently its reduction is an important competitive factor for a companies. The paper introduces in detail the role of the set-up time in production logistics and its reduction possibilities in real-life situations as well. We examined and summarized the application possibilities of simulation modelling for the efficiency increase of the SMED method as well. A future research topic can be the elaboration and realisation of a simulation framework that is able to automatically create the examination models [21].

3.18. Waste reduction possibilities for manufacturing systems in the Industry 4.0

The industry 4.0 has been making a relevant changing at the manufacturing systems' formation and actuation. The appearance of the IoT (Internet of Things) and the cyber physics systems, as well as the big data have created a significant research potential regarding the more efficient actuation and continuous improvement of the logistics systems. The communication between the devices, the information which are derive from the product's tracking, as well as the possibilities in the network collaboration will provide a more widespread optimization possibilities for the manufacturing companies. This research topic introduced in details the process of formation of the industry 4.0, as well as its current devices, possible improvement directions. We also outlined the more relevant research possibilities in the case of the unit loads' manufacturing process' improvement/waste reduction. The value stream mapping's method was created with use of the Toyota's material and information flow diagram. This method's relevant aim is the reduction of the wastes with improvement of the logistics processes. The value stream mapping's method *(*see *Figure 10)* has been simultaneously used for improvement of one product line's logistics processes so far [22].

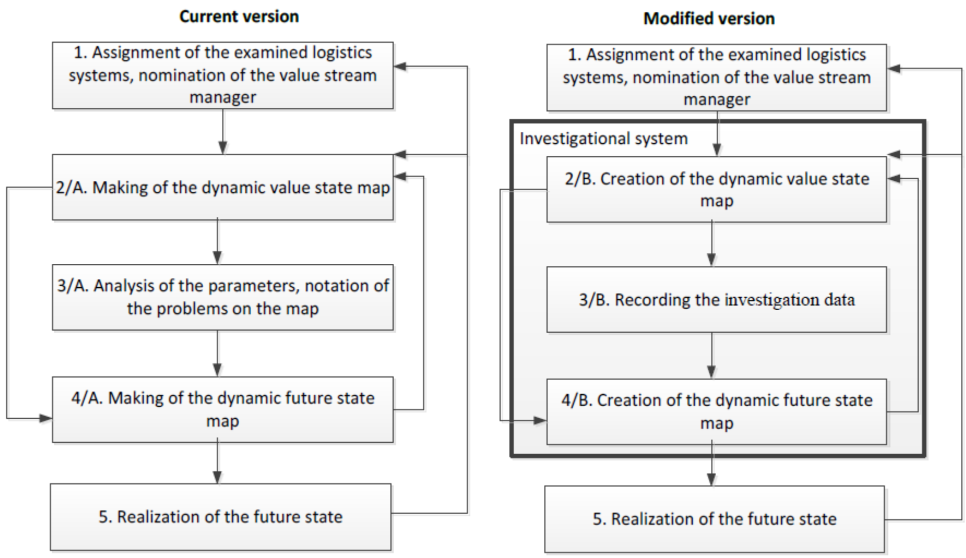

Figure 10. Steps of the dynamic value stream mapping

3.19. Decision method for optimal selection of warehouse material handling strategies by production companies

In practical life, companies have paid small attention to select the warehouse strategy properly. Although it has a major influence on the production in the case of material warehouse and on smooth costumer service in the case of finished goods warehouse because this can happen with a huge loss in material handling. Due to the dynamically changing production structure, frequent reorganization of warehouse activities is needed, on what the majority of the companies react basically with no reactions. This research topic includes a simulation test system frames for eligible warehouse material handling strategy selection and also the decision method for selection [23].

4. SUMMARY

The purpose of the optimal design and operation of logistics systems and processes is quite clear. In today's economy, the pressure is on to make the operations of supply chain from purchasing to distribution more efficient. The supply chain includes the logistic operations of purchasing, production, services, distribution and recycling. These functions are complex. The economical production or manufacturing of complex products and the realisation of related services is a core problem of profitability of companies. The specific challenge of this research project ass to address gaps and deficiencies between the Hungarian researchers and the high performing Member States in the field of design and optimisation of logistics systems and networks. The UMi-TWINN project boosted the work in this field, without the support of this project the above described research would have not been possible.

This research topic focused on both production and service companies and includes a wide set of tools and methods. We are interested to exchange knowledge and be trained on subjects relevant to the design of logistic systems and networks, such as:

- Modelling and mathematical description of systems and processes of materials handling and logistics.
- Development of new equipment selection methods for production systems.
- Meta-heuristic optimisation of large scaled and networking systems, supply chain.
- Design and operation of warehouses and storage systems.
- Computer-aided simulation and scenario analysis of production and service processes.

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LOGISTICS CONCEPTS AND LOGISTICS 4.0

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Abstract: The paper describes the terms Industry 4.0 and Logistics 4.0 as two of the most important trends in production and logistics. Industrie 4.0 (Industry 4.0) is a German term and a synonym for the fourth industrial revolution. It is connected with the common trend of digitalization, virtualization and networking of data and information. The term Logistics 4.0 brands the specific application of Industry 4.0 in the area of logistics. Therefore a new research approach was developed the "Smart Logistics Zone" (SLZ) by Fraunhofer IFF and Otto von Guericke University Magdeburg. This is defined as a scalable examination and action area for the analysis, evaluation, planning, control, regulation and (re-) configuration of logistics solutions [1]. The Smart Logistics Zone differs into logistics objects, logistics processes, logistical systems and logistics infrastructure. Every logistics solution should be built by using all of these four aspects in a free combination by increasing dynamics and complexity. Industry 4.0 and Logistics 4.0 create new business processes. The question is, how will they change the traditional logistics concepts and strategies? The paper answers the following research questions: What are solutions of Logistics 4.0? Are there any successful realized solutions, which optimize logistics at a whole? Which requirements on logistics management will exist according to the criteria of Industry 4.0/Logistics 4.0? Are the classic logistics strategies still valid according to the digital transformation process?

Keywords*: Industry 4.0, Logistics 4.0, logistics concepts, logistics strategies*

1. INDUSTRY 4.0 AND LOGISTICS 4.0

The term "Industry 4.0" was first used in a high-tech-strategy project of the German government. (Compare [2] [3]) The term is based on the nomenclature of software and is used as a synonym for the fourth industrial revolution.

Basics of Industry 4.0 (Compare [4]) are the availability of relevant information in real-time by networking of all elements which are involved in the creation of value, the ability to deduce optimal value-added processes from the information and data at any time and the realization of an information-integrated value-added process.

The use of cyber-physical systems (CPS) best describes Industry 4.0. This means the integration of computation, networking and real, physical things, which provide the base for new business models and business solutions.

The term Logistics 4.0 brands the specific application of Industry 4.0 in the area of logistics. Logistics means the management of the flow of people, animals and things between an origin and the point of consumption to fulfil the requirements of the customer. Relevant technologies of Logistics 4.0 are, e. g. identification, mobile communication, localization, electronic data interchange, data analysis methods and data analytics processing. (Compare [5])

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2. Solutions of Logistics 4.0

Logistics can be differed into procurement (inbound) logistics, production logistics, outbound logistics and disposal logistics. Logistics 4.0 changes the principles and solutions of logistics.

Figure 1 shows some important principles and solutions of inbound logistics by using Logistics 4.0 in connection with Lean management in a simplified way.

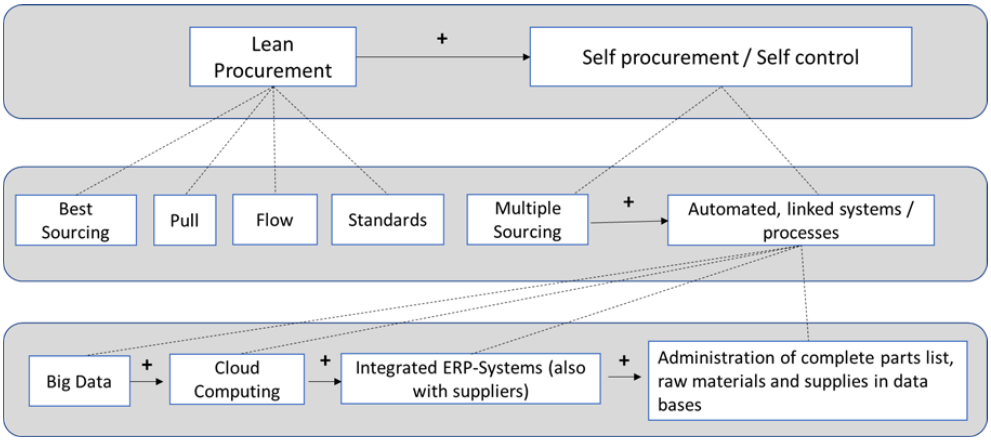

Figure 1. Inbound logistics: principles and solutions (Compare [6], p. 72)

Main target of logistics is to fulfill the customer requirements effectively and efficiently. *Figure 1* shows some targets of inbound logistics to realize an increase of speed, productivity, flexibility and transparency and to reduce costs, waste and failures. There are some principles of Lean production mentioned. These are more than the typical five, flow, standards, pull, synchronization, work cycle, integration, perfection and robustness. Holistic cyber-physical systems (CPS) are important results of Industry 4.0/Logistics 4.0. They realize the networking and automation of transportation, allocation and if necessary the use of storage systems on the basis of digitalization of processes and decentral software control. Therefore, Cloud Computing, Big Data services and decentralized Agent systems are essential. The control of the material flow is initialized by the logistical objects by themselves. They execute their workflows with own software agents.

Typical technical solutions integrate robots, sensor systems, smart products and smart handling-aids. *Figure 2* shows some more typical solutions of Logistics 4.0. (Compare [14] [15])

Smart logistical objects include the use of embedded systems to collect data, communicate and make networking. They use identification (e. g. RFID) and sensor technologies. They create transparency about the identified logistical products/load carriers and their behavior. This information builds the basis for holistic tracking and tracing solutions and for process control. So it changes the processes, where the logistic objects are involved.

Possibilities of autonomous driving have different technical solutions but realize the same task to move, to handle and to transport without a driver/a pilot. There is a great potential to improve the energy efficiency and to increase the capacity of the transport mode and space. Smart vans, trucks and busses have sensors for direction, speed and safety distances. Driving mirrors are replaced by cameras. GPS and WLAN give information about topological characteristics.

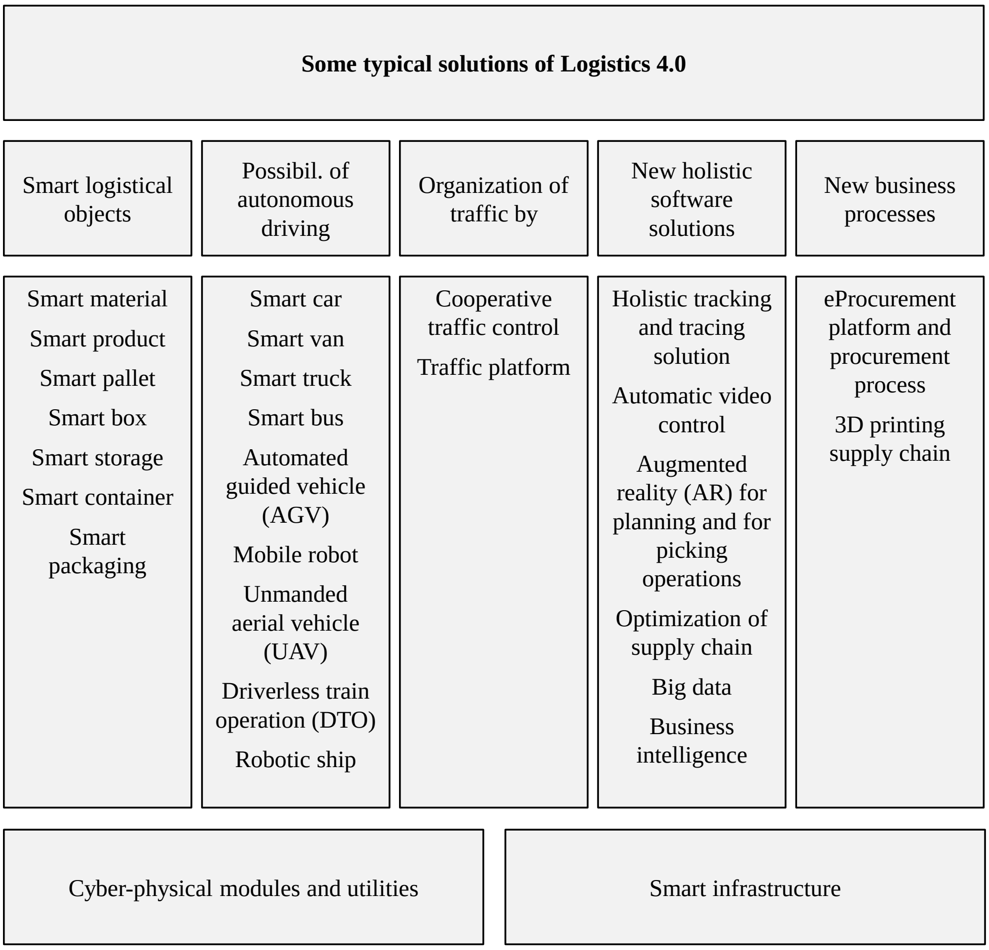

Figure 2. Some typical solutions of Logistics 4.0 (Compare [14] [15])

New models of AGVs and mobile robots use more sensors to get more information, drive autonomously and communicate with each other. They navigate by themselves to places where they are needed. They support e. g. transportation and delivery processes, handling of tools and parts, assembly, quality control and maintenance. The newest solutions of UAV and the self-positioning of trains are also part of Logistics 4.0. (Compare [8]) Robotic ships will have robots, cameras, sensors, radar, sonar and GPS onboard. The navigation is autonomous but could also be centrally controlled. For more information see [9] [10].

Organization of traffic by the cooperative traffic control is based on the recording of the current traffic situation and the adaption of traffic signs and signals while the traffic platform interconnects the intermodal transport and the intermodal movement.

Telematics solutions use technical data to optimize fleet management, vehicle management, driver management and cargo management.

New holistic software solutions (with CPS characteristic) allow new processes. Tracking is useful for position fixing and for the delivery status of the object. Tracing allows a holistic view on the value added chain. Video control is used for documentation, for security tasks and for control of logistics processes. The video sequences are automatically checked and give signals and/or actor activities as reaction to abnormal situations. AR helps to increase the process quality by avoidance of logistical failures and by increasing the efficiency of staff by avoidance of unnecessary searching processes. SCM allows the identification of possible savings and the avoidance of effectivity losses in the framework of a holistic consideration. Big data are based on data analysis methods to discover patterns and other useful information. BI are "the processes, technologies, and tools needed to turn data into information, information into knowledge, and knowledge into plans that drive profitable business action. Business intelligence encompasses data warehousing, business analytic tools, and content/knowledge management." [11]

New business processes realize the business-to-business or business-to-consumer or business-to-government purchase or the new 3D-printing process. New solutions of Logistics 4.0 realize the full process in the kind of a sensor triggered, software integrated, autonomously realized and optimized process. One more example are the freight exchange to conclude subcontracts and to reduce empty runs. Software helps to realize process mining, Business Activity Monitoring (BAM), Business Operations Management (BOM) and Business Process Intelligence (BPI).

Some typical Cyber-physical modules and utilities are smart shelf, shelfs with robots, modular cross-linked conveying systems, robot assistance, smart clothes, data glasses, data gloves.

Smart infrastructure are e. g. smart docks, smart gates or smart ramps. They allow different logistics processes and systems.

According to *Figure 2* we can differ into three levels of Logistics 4.0 realization. Single cyber-physical solutions (CPS) are members of the first level. Holistic cyber-physical systems are members of the second level. New business visions and business processes with CPS are members of the third level.

Now we can also answer the question, if there are any successful realized solutions, which optimize logistics at a whole. The majority of solution in *Figure 2* will only change the fulfilment of existing processes, but some of them will also create new business processes.

3. TARGETS AND MEANS OF INBOUND LOGISTICS IN LOGISTICS 4.0

Which requirements on logistics management will exist according to the criteria of Industry 4.0/Logistics 4.0?

Table I shows the targets and means using the example of inbound logistics according to the Industry 4.0 philosophy.

The question is the following: Are the classic logistics strategies still valid according the digital transformation process?

Table I

Targets and means of inbound logistics according to the Industry 4.0 philosophy [6], p. 100

Organizational targets	**Process-related targets**	**Economic targets**
– Simplification of organization – Liquidation of inflexible links	– Decrease of inventory – Increase of security of supply – Increase of adherence to the delivery dates – Increase of flexibility	– Decrease of acquisition price – Decrease of process costs

Organizational targets	Process-related targets	Economic targets
– Integration of suppliers in the IT – Liquidation of the operative procurement – Extension of the supplier portfolio	– Self-control of procurement – Completely digitalization and autonomy – Increase of the transparency	
by – Interdisciplinary cooperation – Vertical and horizontal integration – Integrated ERP systems (Big data, Cloud Computing)	by – Administration of complete parts list, raw materials and supplies in data bases – Digitalization of processes by Cloud Computing, Big Data services – Integrated ERP-systems – Automated purchase requisition	by – Multiple Sourcing strategies – Full imaging by software – Outsourcing of services

4. LOGISTICS CONCEPTS AND LOGISTICS 4.0

Most logistics concepts are well known in the logistics science, like e. g. Just in time, Quick Response, Continuous Replenishment, Hub and Spoke, Channel Management, Vendor Managed Inventory, Cross Docking, Efficient Consumer Response, Collaborative Planning Forecasting and Replenishment, Electronic Market, Tracking and Tracing, Supply Chain Management, 1PL-5PL, Sourcing strategies (Sole, Single, Multiple, Local, System, Modular, Forward, Global), Milkrun, Kanban, Conwip. (Compare [12] p. 3).

Eight of these concepts were intensively reviewed concerning their appropriateness to Industry 4.0 and Logistics 4.0. These are Kanban, Single and Multiple Sourcing, Milkrun, JIT, Quick Response, Continuous Replenishment and Vendor Managed Inventory. (Compare [6])

In [15] this was be answered using the example of Kanban. Logistics concepts always have a strategic orientation and use special methods and tools to achieve the strategic targets. The traditional Kanban method is a simple control loop operated by self-organization, pull principle and a small security margin. Kanban is realized in a great variety of solutions. The modern Kanban principle is now often used on an electronic base as eKanban. The eKanban is a computer-based, alternative application of the traditional Kanban method. The physical card is replaced by logical parts and orders in a data processing system. The material flow is synthetic calculated by considering customer demands and inventory data. (Compare [13] p. 551). The responds to the previous question is that the Kanban strategy has a still revalidation but in a modified form. Digitalization and globalization change the sourcing organization in the companies. Changes of the global organization, the management of the commodity groups and the integrated cooperation are examples.

4.1. Single Sourcing

The success of a single sourcing strategy depends on the reliability of the supplier. The strong dependence on only one supplier is a negative aspect.

The risk of non-performances increases. Single sourcing strategies prevent technological innovations and reduce times to market in the most cases.

Reduced flexibility and missing competition are negative aspects when approaching the Industry 4.0-concept. The necessity to realize a technological progress represents a conflict for the single sourcing strategy. This strategy also has strict validity limits.

Single Sourcing components are often important strategic parts for the company. There are to supply a great number of parts. The processes are organized by using the philosophy of Just-in-time or of Just-in-sequence. A single sourcing strategy is also useful to procure C-parts, because there is no common development work necessary while reducing material costs.

4.2. JIT

Just-In-Time-strategy has a positive influence on achieving the goals of production logistics according to Industry 4.0 requirements. The JIT-philosophy supports the flow idea and the kind of implementation of future technologies and processes in the Industry 4.0 age. The pursuit of holistic CPPS is supported by the strong integration and permanent cooperation with suppliers. This requires standards in integrated IKT-systems as well as common used physical technics. The vision describes a self-controlled system that operates in a network with other systems. The JIT-strategy is still valid.

4.3. Quick Response (QR)

The main idea of QR is the automation of the supply chain between supplier and purchaser by using IT applications. The contents of QR enhance the JIT concept. The enhancements are related to optimized networks and automated processes between companies and their suppliers. That is why there is a big intersection between the fundamental ideas of Industry 4.0-and the QR-theory. QR is still valid.

4.4. Continuous Replenishment (CR)

The CR strategy realizes a cooperative, automated recall system. CR is the next level of Quick Response according to complexity and effectiveness. QR demands data exchange. Continuous replenishment changes the roles. The CR strategy is still valid.

4.5. Vendor Managed Inventory (VMI)

VMI-partnerships require a high level of cooperation, much more than data exchange means. VMI-partnerships have advantages for both companies. The supplier can reduce costs, producing companies can operate flexible due to current market conditions and trends. They can guarantee an agreeded service level. Most of the process triggered requirements of Industry 4.0 are fulfilled. The organizational structure is simpler than before due to outsourcing of processes. The VMI is still valid in a more comfortable kind.

4.6. Milkrun concept

The milkrun concept is often used in intralogistics. The concept is reviewed in the area of procurement logistics in this paper. The costs of logistic activities have a big influence on the price of products. The milkrun concept helps to optimize sourcing and transportation processes. This optimization will be pushed further by Industry 4.0 concepts. Intelligent logistical objects, networking and implemented, integrated IKT-systems can considerably improve the milkrun-processes. The digitalization simplifies the planning of the closed loop. The processes will be more transparent than before. The milkrun-concept is still valid and will permanently increase in the future.

5. THE VALIDATION OF MULTIPLE SOURCING STRATEGY

Table II analyses how the Multiple Sourcing Strategy supports the targets of inbound logistics in the sense of Industry 4.0/Logistics 4.0.

Logistics concepts have always a strategic orientation and use special methods and tools to achieve the strategic targets.

Multiple Sourcing: A multiple sourcing concept is a good possibility for companies to spread the demands. This creates permanent improvement process though competition. The strategy is characterized by independence from suppliers. The company can use different options. No delivery bottlenecks should exist. The company is able to respond with a big flexibility. Thereby the concept has a regional, national or also global dimension. Multiple sourcing processes control a great number of markets on a wide base and the corresponding enhancements too. It is also possible to get short-term profit where possible. The digitalization is a big chance to facilitate watching the markets, proofing and adapting contracts, realizing supplier validations and the whole communication and information process. Multiple sourcing signify a great flexibility, but also more expenses to take care of all suppliers. An automatic e-procurement simplifies the processes and is able to react fast to different conditions. This strategy is still valid and will permanently increase in the future.

Table II
Analysis of targets of the inbound logistics in Logistics 4.0 by using Multiple Sourcing Strategy
(Compare [6], p. 108)

TARGETS OF INBOUND LOGISTICS (LOGISTICS 4.0)		MULTIPLE SOURCING STRATEGY	
ORGANIZATIONAL TARGETS	Simplification of the organization	–	High expenditure for information and logistics
	Liquidation of inflexible links	++	The vertical integration is supported by technological innovations
	Integration of suppliers in the IT	+	Integration in IT is absolutely necessary

TARGETS OF INBOUND LOGISTICS (LOGISTICS 4.0)		MULTIPLE SOURCING STRATEGY	
	Extension of the sup-plier portfolio	++	Commitment of several suppliers
PROCESS- RELATED TARGETS	Decrease of inventory	+	Ordering of small batch sizes
	Increase of security of supply	+	Small risk by variation of suppliers
	Increase of adherence to the delivery dates	0	Defaults are possible, but variation of suppliers
	Increase of flexibility	++	By integration of several suppliers with slack links
	Self-control of procurement	0	More expenditure than Single Sourcing has, but Industry 4.0 technologies are possible
	Completely digitalization and auton-omy	++	Requirements for the use of effective Multiple Sourcing
	Increase of the transparency	+	Full integration in IT
ECONOMIC TARGETS	Decrease of acquisition price	+	Advantages by competition, but higher costs by missing quantity discount
	Decrease of process costs	+	Still high costs by high expenditure for information and logistics

– NEGATIVE IMPACT
\+ POSITIVE IMPACT
++ HIGH POSITIVE IMPACT
0 NO IMPACT

6. CONCLUSION

This paper gives an overview about the basics and ideas Logistics 4.0. The paper answers the following four questions of research: (1) Are there typical solutions of Logistics 4.0 known? There are seven groups of solutions of Logistics 4.0 characterized in *Table I*. (2) Are there any successful realized solutions, which optimize logistics at a whole? There are only some new solution which create new business processes. The majority of solutions change the ful-fillment of existing processes in the sense of process improvement by using elements of CPS. (3) Which requirements on logistics management will exist according the criteria of Industry 4.0/Logistics 4.0? Therefore *Table II* shows the targets and means using the example of in-bound logistics according the Industry 4.0 philosophy. This is a combination of a lot of well-known targets from the Industry 3.0 area and only some new considerations. (4) Are the classic logistics strategies still valid according the digital transformation process? Eight logistics concepts were intensively reviewed according their appropriateness in the sense of Industry 4.0 and Logistics 4.0. (Compare [6]) The paper shows the results of the Multiple Sourcing Strategy. The Multiple Sourcing strategy is still valid in the sense of Logistics 4.0 but in a modified, holistic, computer-integrated form.

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ARTIFICIAL INTELLIGENCE IN LOGISTICS APPLICATIONS AND ALGORITHMS

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Abstract: The artificial intelligence undergoes an enormous development since its appearance in the fifties. The computing power has grown exponentially since then, enabling the use of artificial intelligence applications in different areas. Since then, artificial intelligence applications are not only present in the industry, but they have slowly conquered households as well. Their use in logistics is becoming more and more widespread, just think of self-driving cars and trucks. In this paper, the author attempts to summarize and present the artificial intelligence logistical applications, its development from the beginnings and impact on logistics and share some thoughts about the future.

Keywords: *artificial intelligence, AI logistical applications, neural nets, robots, self-driving vehicles, augmented reality, optimization algorithms*

1. INTRODUCTION

The term "Artificial Intelligence" was created by John McCarthy, who is known as the father of the artificial intelligence, he mentioned it firstly at a conference at Darthmouth in 1956 [1]. This was the first conference on this topic. The first testing method of the artificial intelligence was created by Alan Turing in 1950. One of the earliest testing methods, according to this, if an interrogator gives written questions to another person and a machine behind a screen and they will answer in writing, if the interrogator cannot decide in 5 minutes which one is a person and which one is a computer then the artificial intelligence passed the test. [2] Of course, the Turing test got a lot of criticism, mainly because the simulation of the dialogue is only a small part of the intelligence. A Loebner prize was established in 1990 for an artificial intelligence which can pass the test, but no program passed it in a convincing way ever, however a smaller prize is awarded annually for the program which is the closest. [3]

2. NEURAL NETS

The first artificial neural network was created by Frank Rosenblatt in 1958. This modelled the functioning of the human brain with artificial neurons, how it is processing the visual information and how it can identify various objects [4]. The first practical application was the optical handwriting recognition, this quickly became industrially applicable and quickly spread among the postal companies.

After the USA (1965) and then Japan (1968) [5], in Hungary (1978) the optical recognition of the handwritten postal codes was introduced [6], this system was based on a neural network character recognition application *(Figure 1)*. Later, the systems were able to identify whole handwritten addresses with great precision. The neural networks have been extensively used since then in almost all segments of the artificial intelligence, including the field of self-driving cars, to identify and classify visual information.

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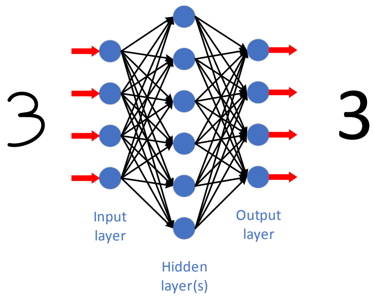

Figure 1. Character recognition using neural network

3. CONSUMER SEGMENT

The forerunner of artificial intelligence in the consumer segment was the data mining on the extensively collected data related to loyalty cards in the eighties. Companies launched loyalty programs, issued point-collecting cards, so they were able to connect the consumers to the purchased products, and they built huge databases that were analyzed using various data mining techniques [7]. Later, the extensive online data collection was appeared, and the deeper analysis of consumer behavior began.

The software solutions use machine learning methods to analyze our consumption patterns, considering our orders, searches, the web pages visited, the contents of our emails, even our spoken words for effective profiling. They offer products for purchase based on this. This product recommendation method is very effective. Amazon experienced a 29% increase in sales after implemented his product recommendation system. At present, products sold on product recommendation account for 35% of Amazon's turnover [8].

Household and personal assistants appeared whose can communicate in natural language, they can even order online, which instantly lead to serious security problems [9], but these home assistants also collect data on user habits too. These applications can, on the one hand, make life easier and, on the other, raise a lot of privacy and data handling problems.

Automatic ordering applications have been released, that are able to order the product at the push of a button *(Figure 2)*. Analyzing their usage, a big part of the inventory can be calculated effectively.

Figure 2. Amazon Dash, Order products with a push of a button, source: Amazon

It is estimated that the volume of data generated by the world will increase by 40% over the previous year *(Figure 3)* [10].

To analyze this huge data volume in the late 90's appeared the big data techniques and then the machine learning. These systems are able to determine relationships and regularities based on the data [12].

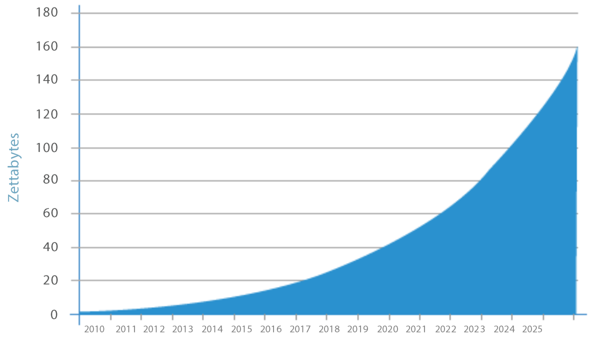

Figure 3. The amount of data created by worldwide [11]

Based on the detected regularities, they are able to make better predictions, reduce inventory levels, increase availability, and increase the safeness of supply of production. The recent research studies extend the machine learning to the entire supply chain, this is the so-called Smart Manufacturing Supply Chain, SMSC [13].

4. ROBOTS

Manufacturing and logistics do not exist without each other [14]. Thus, practically the increase in the automation of the production has led to an increase in logistics automation too. The robots appeared not only in production but also in material handling, transportation, warehousing etc. With the introduction of Industry 4.0, automation and the need to increase the degree of automation have boosted considerably, and currently the lack of workforce also favors the spread of robotics in production and in logistics also.

In the beginning, the logistical use of robots was held back by the fact that early robots were stationary [15]. They had little intelligence, basically the same procedure was repeated 24/7, but logistics often required movement and more complex operations. With the development of camera systems, laser scanners and sensor systems, various grippers, some of that are modelling the human gripping, robots are now even able to harvest strawberries *(Figure 4).*

Figure 4. Strawberry harvester robot [16]

Research has now been carried out in several areas to extend the logistical application of robots, such as container loading and unloading robots *(Figure 5)*, picking robots, warehouse robots, and collaborative robots.

Figure 5. Container unloader robot [17]

The use of warehouse robots was accelerated by large service providers like Amazon. In Amazon 2016, 45,000 robots *(Figure 6)* have been used globally, this number has risen to 100,000 by 2018 [18], but they are not able to completely replace human labor.

Figure 6. Amazon warehouse robots [19]

The present largest developmental step is the use of robots which cooperate with humans, these are the so-called cobots [20]. Current research has shown that they can increase efficiency by up to 50% [21].

The cooperating robots *(Figure 7)* raise a lot of security issues, their security-related recommendations are specified in ISO/TS 15066:2016 [23].

Figure 7. Cobot [22]

5. SELF-DRIVING VEHICLES

The first definition of self-driven vehicles come from the U.S. Department of Transportation: "Self-driving vehicles are those in which operation of the vehicle occurs without direct driver input to control the steering, acceleration, and braking and are designed so that the driver is not expected to constantly monitor the roadway while operating in self-driving mode." You can notice the fact, it is explicitly stated that the driver must be present in the vehicle [24].

Self-driven vehicles use different sensors to measure surrounding traffic, various objects, obstacles, some of these sensors, such as the laser radar, LiDAR *(Figure 8)*, in unlike the human driver, can see in the dark, so they allow even the night driving in totally dark environment. There are 6 levels of automation [25]:

- Level 0: A human driver performs all the operations.
- Level 1: Partial support, the system can accelerate, slow down, can do steering, but not simultaneously.
- Level 2: A driving aid system that can accelerate, slow down and do steering at one time.
- Level 3: The vehicle can drive itself under certain circumstances, but the driver must be able to take control at any time.
- Level 4 Complete driving in certain circumstances, such as in HD mapped areas, other areas require driver intervention.
- Level 5: Full driving, no driver Needed.

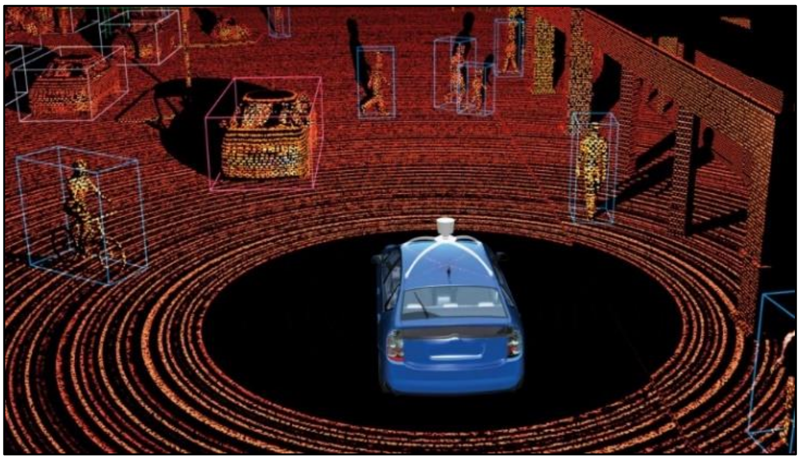

Figure 8. LiDAR in operation [26]

At the time of the release of this article, Google Waymo is the only one to reach the 4^{th} level of automation and now they got the permit to test fully driverless cars in Mountain View California.

However, not only the passenger transportation, but the freight industry has also started the developments in self-driving. In 2016, Komatsu introduced self-driven dumpers in Australian mines *(Figure 9)*, which can work continuously 24 hours without human intervention [27]. However, this is a special application without any traffic or with little traffic only. Similar self-driven vehicles have also appeared in agriculture, as there is no traffic expected within the given area.

Figure 9. 416 tons Komatsu dumper [26]

The self-driving is spreading in the field of commercial transportation also. Currently, most of the major carmakers are conducting research projects in this field. According to the promises, in 2019, Tesla Semi, which is an electric powered self-driving truck *(Figure 10)* will be presented to the public. Tesla promises full self-driving, but according to the current situation, the vehicle is probably reaching level 3 or 4, which can be upgraded later with software updates. It is estimated that around 2030 we will reach level 5 [28].

Figure 10. Tesla Semi, self-driving fully electric truck, source: Wikipedia

6. AUGMENTED REALITY

Augmented Reality or Mixed Reality is a kind of expansion of the reality when virtual elements are projected into the real environment. For example, a virtualized image can be seen with a mobile phone or special glasses.

One of the most recent definitions of the extended reality is Milgram's Reality-Virtuality Continuum *(Figure 11)* [29]. From the graph, it can be seen that, starting with the real environment on the left, adding more and more virtual environment objects, we get to a completely virtual, simulated environment that has no real elements. Practically leaving the two extreme states we are in the augmented reality or mixed reality.

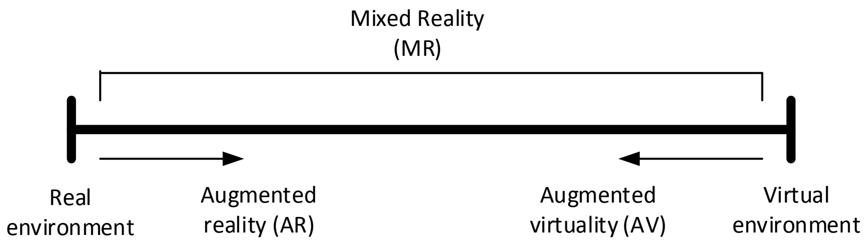

Figure 11. Milgram's Reality-Virtuality (RV) continuum

The first VR system *(Figure 12)* was made by Ivan Sutherland in 1968, but it was so heavy, it must be suspended on the ceiling, portability was not a question [30].

Figure 12. First head mounted VR system, 1968

The creation of augmented and virtual reality applications started with computing performance increase in the early 1990s. The first ever augmented reality system, the Virtual Fixtures *(Figure 13)*, developed by Louis Rosenberg in the US Air Force Armstrong Laboratory, was used mainly by robot aided remote controlling, he was using several procedures to eliminate the shortcomings of the primitive 3D graphics of that time [31].

Figure 13. Virtual Fixtures, first AR system, 1992

Computing needs of these types of applications were not available at this time, especially in small sizes, large computers were expensive, graphics were very primitive and low resolution, so the applications were limited, does not look real and did not spread. Over the next 15 to 20 years, augmented reality research was funded by industry giants and military research laboratories, then the augmented reality slowly spread in computer games, industrial applications are not yet available at this time.

The first major breakthrough was the launch of Google Glass in 2013, which has been sold in limited numbers [32]. This can be worn as a voice-controlled device, it was already suitable for augmented reality applications. Research has accelerated, with more companies appearing with their own products such as Lenovo C1 or Microsoft Hololens *(Figure 14)*.

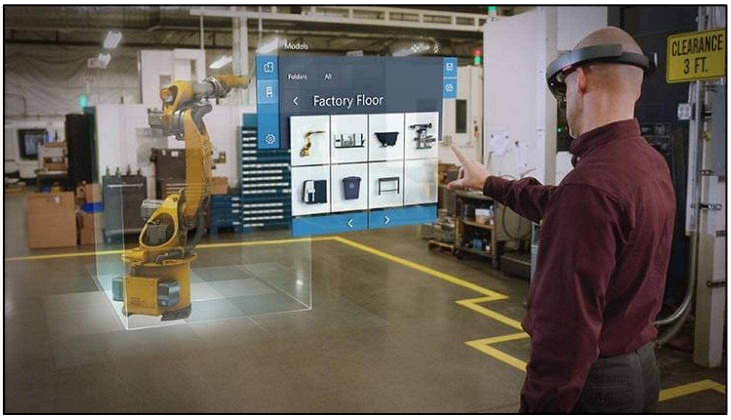

Figure 14. Microsoft Hololens, source: Microsoft

With the development of hardware, industrial applications have begun. Logistics research first started at the DHL and SAP research laboratories, and later, as hardware became cheaper, more and more companies began to develop applications. One of these is the KNAPP AG Pick-by-Vision system *(Figure 15)* [33]. Which guides the picking person with visual aids for the specified goods, increasing order picking speed and minimizing errors.

Figure 15. KNAPP KiSoft Pick by Vision system, source: KNAPP

7. OPTIMIZATION ALGORITHMS

In the field of artificial intelligence research, many optimization algorithms are used, which can be used to efficiently solve logistics problems. In the field of artificial intelligence, most of the problems can be solved by searching through the problem's state space *(Figure 16)* [34].

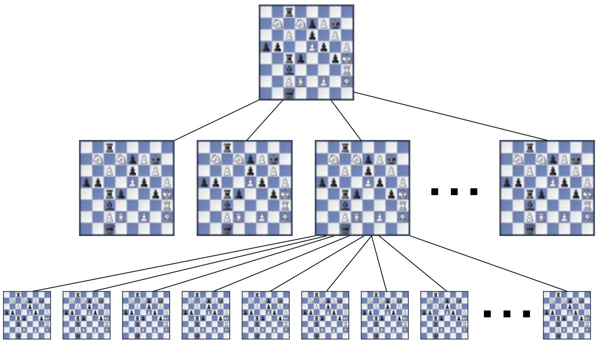

Figure 16. A graph representation of the state space of a chess game [35]

For example, layout design algorithms searching in tree structures, while robots use local searches when using grippers, and the learning algorithms also use optimizations based on searches. [36].

Logistic problems in real life are usually very diverse, with many conditions, often have very high variable count. One of the simplest and most basic logistical problems is to define the shortest path. Although the problem is simple, it did not become outdated over time. Algorithms that solve the shortest path problem are currently widely used, for example, in route planning systems, GPS devices, navigation software, robotic devices. There are several algorithms for this, the most important ones are these:

- Disjkstra algorithm *(Figure 17)*, 1956
- Bellman-Ford algorithm, 1956
- The A* algorithm, 1968
- Floyd-Warshall algorithm, 1962
- Viterbi algorithm, 1967
- Johnson Algorithm, 1977 [37].

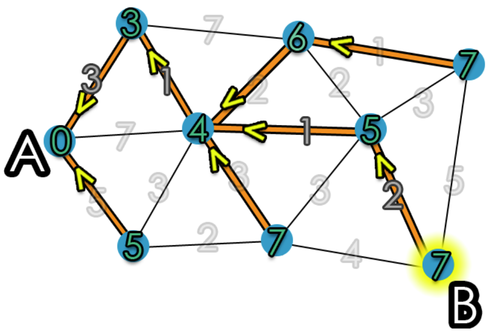

Figure 17. Dijsktra algorithm [38]

Perhaps the most well-known logistic problem, the "holy grail" of logistics optimization, is the Traveling Salesman Problem (TSP) and its variants, such as the Multiple Traveling Salesman Problem (MTSP). Since the TSP problem is NP-hard, so with exhaustive search it can be solved on very small problems in practice. The TSP problem has been solved by the following heuristic algorithms [39]:

- Nearest neighbors' algorithm, 1973
- Christofides algorithm, 1976
- Lin-Kernighan heuristics, 1973
- Genetic algorithm, 1963–1975
- Simulated cooling, 1983
- Taboo search, 1986
- Ant Colony algorithm, 1991
- Particle Methods, 1986

Of course, under real circumstances "clear" TSP problem does not exist. Mostly, the MTSP problem and its variants appear, such as the time window MTSP problem, or MTSP problem with real world conditions *(Figure 18)*.

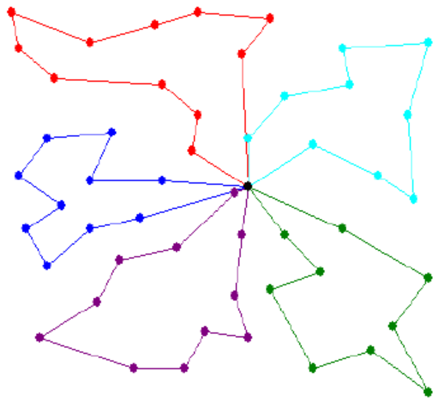

Figure 18. A simple MTSP problem [40]

If we include realistic conditions such as one-way roads, working hours, driving time, and fuel constraints, then complexity can be increased so that the runtime of heuristics often falls outside the foreseeable time range with the current computing capacity. Thus, such problems are solved by metaheuristic methods, directed heuristics.

The multiphase algorithms are popular at present, they include usually two phases – a fast global search and a slower local search. In the first stage, the state space is narrowed by a fast heuristic, for example clustering, second phase use this heuristic method output for a starting point, for example, by initializing a heuristic method with an output of a randomized search [41] or using adaptive methods that modify the heuristic parameters during runtime and generally provide methods for avoiding stuck into local optimum [42].

In addition to these algorithms, artificial intelligence uses a number of other algorithms and methods, such as probability algorithms, fuzzy logic, regression, clustering, pattern recognition, enhanced learning and speech processing that are not closely related to logistics but may be present in logistics applications. The artificial intelligence area growing exponentially nowadays *(Figure 19)*, the development practically exploded.

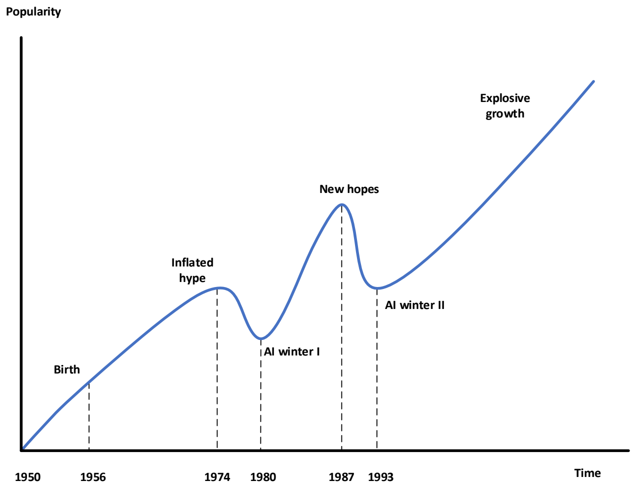

Figure 19. AI timeline [43]

Today, commercially available hardware and software packages exists such as the Intel Nervana NNP – Neural Network Processor *(Figure 20)*, which is an artificial intelligence accelerator specifically designed to accelerate machine learning. Virtually every day new hardware, new applications and new algorithms are being created.

Figure 20. Intel Nervana NNP
source: ai.intel.com

8. FINAL THOUGHTS

At present we distinguish three types of the artificial intelligence. The first type is the weak artificial intelligence or narrow artificial intelligence which programmed to solve one task only. The second one is the strong artificial intelligence or artificial general intelligence which is close to the human intelligence or it is about the same level. The third and ultimate type is the super artificial intelligence which goes beyond the human intelligence in every aspect [44]. However, we just implemented the narrow AI and use it in special areas, like driverless vehicles or computer vision systems or in chess games. The development of the AI is a rapidly growing area. Researchers, philosophers and futurologists are trying to predict the evolution of the artificial intelligence. The last two types of the artificial intelligence are just fiction now, but it can be changed in the future, the predictions vary [45], [46]. At present maybe due to the current promising results and current predictions a lot of critical voices emerged to warn the potential dangers [45], [46]. It might be dangerous if we can't use them well. We still have a lot to learn about the human robot interactions, machine learning and AI controlled machines. They are not just in the industry but in the homes as well, they will appear in the everyday life in growing numbers, so this is inevitable.

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INTRODUCTION OF DEMO3D INTO THE SCIENTIFIC EDUCATION OF MATERIAL HANDLING

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Abstract: Using of advanced machines and methods requires highly educated engineers, who gain their basic knowledge at universities. In the aspect of material handling, the Institute of Logistics of the University of Miskolc (LOG) is one of the leading education centres in Hungary, so its teaching materials, methods and devices have significant effects to the knowledge of future logistic engineers. In this paper, we describe the state of the art of planning of material handling and the education structure of LOG. Main objective of this paper is to present developing possibilities of the scientific education of LOG with some help of the Institute of Engineering Logistics of TU Graz (ITL) in the frame of project UMi-TWINN. One of the most important results of the project is the application of the Demo3D software for the education of material handling. The developed examples, videos, sheets and other documentations are directly usable in the teaching curricula of different courses of LOG.

Keywords: *planning of material handling, scientific education, Demo3D, simulation*

1. INTRODUCTION

Nowadays, material handling processes are much more complex than some years ago, and they have very important role in every field of the industry. Handling processes use advanced, automated machines; planning and operation of the handling machines requires effective computer methods.

To use advanced machines and methods we need highly educated engineers, who gain their basic knowledge at universities. In the aspect of material handling, the Institute of Logistics of the University of Miskolc is one of the leading education centres in Hungary, so its teaching materials, methods and devices have significant effects to the knowledge of future logistic engineers.

In this paper we describe the state of the art of planning of material handling and the education structure and courses of LOG. After it, we present the developing possibilities of the scientific education of LOG by the help of the Institute of Engineering Logistics of TU Graz in the frame of project UMi-TWINN.

2. PLANNING OF MATERIAL HANDLING

Material handling is an activity for short moving of materials, semi-finished units, finished products or units, without any changing of the goods [1]. Material handling equipment is a special machine used for the realization of given material handling tasks. Application of a

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single handling machine in effective, advanced production processes is not considerable, in generally a materials handling system has to be applied.

Material handling system means a group of machines which have to be used together to realize the related material handling tasks. The design and operation processes of material handling systems are much more complicated than single equipment, because they integrate the characterisations of the individual machines. Through the integration the parameters of the different machines can be changed, their effects can be more intensive or weaker, in certain cases some new characterisation can be appeared. Besides them there are some special material handling tasks which can be solved only in systems (for example: waiting phase of a handling machine).

During the planning of material handling systems we are looking for handling machines for complex material handling tasks and synchronizing their operation. The solution can be task-based or system-based *(Figure 1)*.

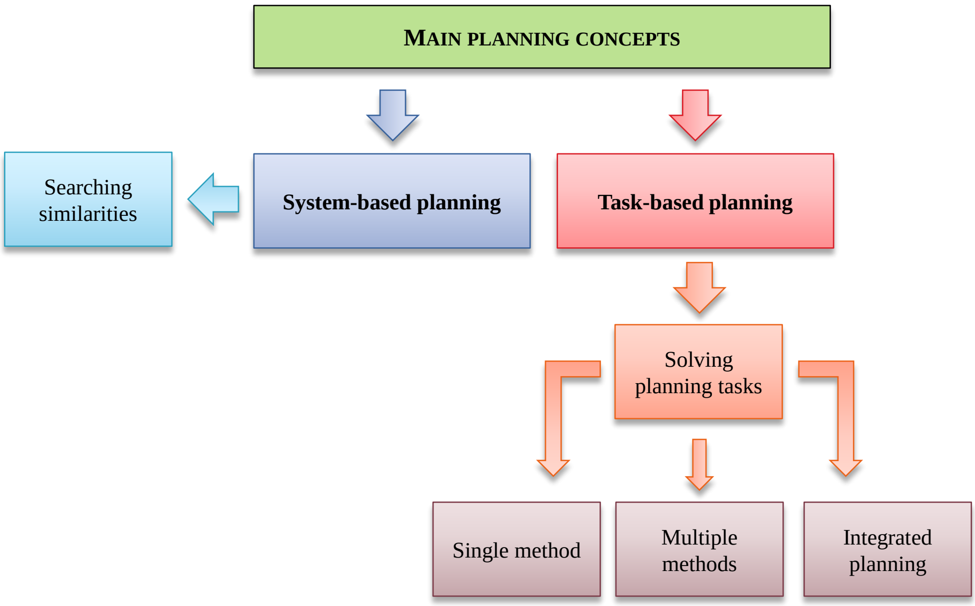


Figure 1. Planning concepts for material handling

In system-based approach, we analyze the whole system and look for a similar existing one to apply its handling solutions to our system [2]. Similarity of the system can be found in objects, handling tasks, technology or handling devices. During the planning process, we are searching in a special database for a similar system-structure and trying to adapt its handling solutions. To realize this planning concept, we need a special database, which are built on certain system types [3]. Typical application of this approach is the duplication of production processes, which is used by multinational companies to multiply their production [4].

In task-based approach, we realize the planning with the use of different individual planning tasks. Main advantage of it is the using of material-flow parameters, which enables exact, mathematically described calculations. This approach is much better published and used in the practice, but the application in complex systems is not so easy. Main problems of this approach are the large number of planning tasks, their complexity and the iterative solution process *(Figure 2)*, which result three different application cases in practice: single-task planning, multiple-task planning and integrated planning process [5].

During single-task planning we can solve only one planning task (e. g. [6]) in any kind of system. The complexity of the solution method depends on the scale of the handling system. Multiple-task planning means the solving of a group of planning tasks, where usually the methods for the single-task are used, but this concept is basically more complex for any system [7]. Integrated planning tries to solve all the planning tasks in one process, but because of the large number of tasks and the iterative procedure it is usable only for simple handling systems [8].

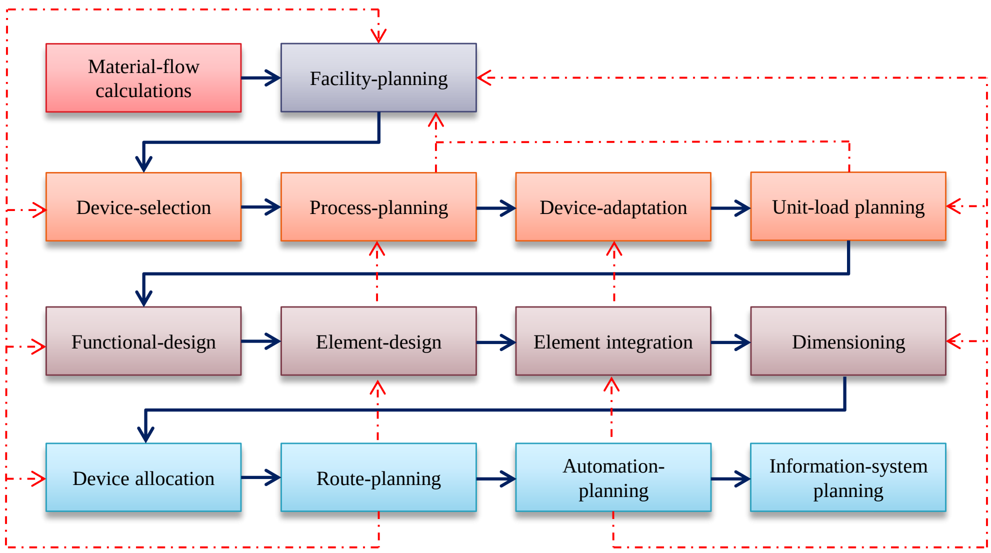


Figure 2. Structure and steps of integrated planning

Because of the complexity of the production system and the planning processes, there is no chance to make generally usable method for the planning of handling systems. Integrated design processes give the best device for the planning, but their very complex characterization makes the application too hard. There are different initiatives to solve these problems using different methods [5], but non-of them resulted general solution so far.

Another aspect of the planning process is the solution concept which can be analytic, knowledge based and hybrid methods [9].

Analytic methods use mathematical formulas related to given objective function to find optimal handling equipment based on material handling parameters [10]. Knowledge based methods use special database of practical experts which includes their knowledge about material handling equipment, and look for results by the comparison of the material flow and handling device parameters [11]. Hybrid methods use knowledge-based procedures and analytic formulas together to select optimal materials handling solution combining their characteristics [12].

Advanced methods for planning of material handling machines and processes use different computer software in the practice, so the applied IT techniques influence the available solutions.

3. COMPUTER METHODS IN PLANNING PROCESSES

Because of the large differences of material handling systems and the complexity of handling tasks, there is no universal solution for planning of material handling processes. In most cases, engineers use the task based approach but only for single tasks or for small group of tasks.

In certain cases, if the planning problem is simple and the tasks can be easily solved, designers are able to give solutions based on their experiences. If it is possible to reduce the complexity level of large planning process, it can also help to find easy and quick solutions. In other cases, planning process is usually complex and complicated, so it requires sufficient practice and application of advanced methods and computer software. Most important characterisations of advanced planning solutions are focusing on given task-groups, using advanced computer methods and the integration of different planning solutions.

Because there is no universal planning method, the applied computer devices have to be suited to the analysed handling tasks, so many different methods and software are applied during the planning process. In advanced planning processes, applicable computer methods can be sorted into different categories based on their characterisations and application fields:

- CAD methods
- Knowledge based systems
- Simulation methods
- Virtual reality solutions
- Optimisation methods

3.1. CAD methods

Computer Aided Design methods (CAD) are computer devices which help designers and engineers in their planning and design activities. CAD methods used in the advanced industrial and scientific processes are 2D and 3D planning software [13].

Main application fields of CAD methods are the design and development of machine elements, production units, industrial products and other parts and elements. There are many CAD methods in the industry which have been effectively applied from decades in engineering (AutoCAD [14], CATIA [15], CadKey [16] etc.).

CAD software is mainly applied in planning process of material handling for the design of machine elements and units of handling equipment and their building structures. Besides some of them are suitable to model and demonstrate complete handling equipment.

3.2. Knowledge based systems

Knowledge Based Systems (KBS) are computer programs which use Artificial Intelligence (AI) techniques to solve complex problems based on specific experiences of human experts. Knowledge Based Engineering (KBE) is a technology able to merge the capabilities of conventional Knowledge Based Systems with computer aided analysis and design systems (CAE and CAD systems) [17]. KBE systems enable to insert the result of the knowledge based calculation procedure directly into the design process of machine elements using special software solutions.

For the realisation of KBE systems three different solutions were published in the international literature [18]:

- Augmented CAD systems with KBE
- Full KBE systems and
- Linked KBE/CAD solutions

Augmented CAD systems with KBE are found in many different CAD environments and have different scopes of operation [19]. Main principle of this concept is that the KBS solution has to be integrated into the CAD environment. Well known commercial products are Knowledge Ware within CATIA and Knowledge Fusion within NX [20].

Full KBE systems are object oriented highly advanced generic and super ordinated software programs which apply captured knowledge to design processes by using different visualization tools [21]. The systems must drive the way of design automatically by using various validation rules and should not criticize pre-generated results leading towards engineering process automation. An investment into a full KBE system is nowadays only seen in automotive and aeronautic sectors [22].

Linked KBE/CAD solutions means a new approach, in which existing KBE and CAD solutions are linked by special software. The basic idea behind this concept lies in using separated system elements for knowledge capture and use as well as geometry representation. In its most basic form the two core elements can be a calculation scheme implemented in a capable software tool and a parametric CAD model. In order to combine them to a full featured application they are bidirectional interconnected to each other via a specific interface [7].

What KBE means within Material Handling Equipment Design (MHED) is best described in [23]. The first is to specify input parameters in form of rules and constraints classes for KBE in MHED. Some fuzzy criteria such as shape design, leading to customer acceptance or not, and system integration are relevant as well as the "harder" facts concerning manufacturing and costs, which can be formulated within rules much more easy. As every MHE is determined by the demands of throughput (in tons or pieces per hour) it is necessary, to define throughput as the major input parameter [23].

3.3. Simulation methods

Simulation is a device to model real processes and evaluate their states, changings and other process elements [24]. Simulation methods usually applicable for modelling of given processes, however they can be adapted for different similar process variations setting their parameters in.

Types and characterisations of simulation processes are depend on the applied modelling. Calculation schemes, environment and parameters are taken into account. Based on the large variation of methods a huge number of simulation software had been developed during the last decades.

There are also several simulation methods used for the material handling and logistic processes, modelling different elements of the handling procedure (e. g. [25]).

The main application field of simulation software in material handling is the modelling of operation and taking the effects of stochastic changing parameters into consideration. They have smaller influence during the planning process of material handling, but they have importance in previous analysis of the designed machines and systems.

The most often used simulation methods in material handling are PlantSimulation [26], FlexSim [27], ExtendSim [28], Enterprise Dynamics [29] etc.

3.4. Virtual reality solutions

There are different definitions for virtual reality (VR) [30], but in the aspect of the planning of material handling we can define virtual reality solutions as devices for presentation of simulated 3D objects and their environment. In practice, VR solutions can be used for planning or teaching of handling processes.

For planning purposes we can apply simulation software to present and simulate the operation of handling machines and systems, or 3D CAD software to design their building elements, so they are suitable to demonstrate and analyse the application and operation problems of material handling machines [31].

3.5. Optimisation methods

Optimisation is a new and effective technique to find the best solution for a given task or process. During the optimisation process we create different variations and analyse their efficiency to find an optimal solution. The increasing of the computing capacities and calculation speed of the computers resulted many new methods and algorithms in the practice (e. g. [32]), but this device mainly suit for increasing the operation efficiency, application in the planning process is not so frequent.

4. USE OF DEMO3D ® FOR LOGISTICS PLANNING

Within logistics planning, there is a trend towards shortened planning cycles with improved planning quality using high-end digital planning methods. A specific approach for digital validation of planning results is so-called "virtual reality". Using these solutions within the system planning process it is possible to animate logistics systems within 3D representations in a realistic manner. The resulting virtual reality models create a high level of understanding of the plant. Design alternatives can be evaluated interactively and the system can be viewed from any angle with virtual "walk through". The use of virtual reality solutions thus leads to a more efficient planning process and is increasing the planning quality [30], [31].

Classic scope for the use of virtual reality environments is detected in the area of sales and layout planning. Also for scientific teaching in the field of intralogistics, the use of virtual reality environments seem appropriate. Design and functionality of modern intralogistics systems are complex for purely theoretical knowledge transfer in teaching [33]. With the application of 3D animated realistic models, students get a better understanding of intralogistics equipment and plants. Specific characteristics of the logistics systems are in focus:

- design, layout, structure and components of logistics plants,
- functionality, strategies and mode of operation of logistics equipment,
- technical and performance parameters of technical devices.

4.1. Software Solution Demo3D ®

The software tool Demo3D ® provides a user-friendly and interactive virtual reality environment for the animation of logistics facilities. The software provides comprehensive layout planning, animation and presentation capabilities for logistics and planning processes.

The representation of material flows and device movements is close to reality. Physical properties such as gravity, friction and much more are considered. In addition, the user can decide whether he wants to present plants on detailed level of light barriers and drives or rather on a more abstract level [31].

4.2. Usage of Demop3D ® in practice

There is a variety of predefined elements available from libraries for modeling the 3D layouts. The elements can be adapted with numerous parameters. This affects both, the design as well as the function of the elements. Based on the integrated snap function used for creating the model layout, executable models are created automatically. If necessary, the models are adjustable in terms of material flow control (based on JavaScript or ladder logic).

The following element libraries are particularly supported [31]:

- Conveyor technology (continuous and discontinuous conveyor)
- Warehouse technology (automatic high-bay warehouses, manual warehouses)
- Industrial trucks (forklifts, automated guided vehicles)
- Load handling (robot, palletizing)
- Sorter (shoe sorter, tilt tray sorter)

In addition to use standard elements, the software also offers the opportunity to develop separate parameterized components (which can be stored in new libraries). For demonstration, a "walk through" for the animated plant is defined. For illustrative purposes, the software offers further functionality such as video recording with arbitrary camera angle.

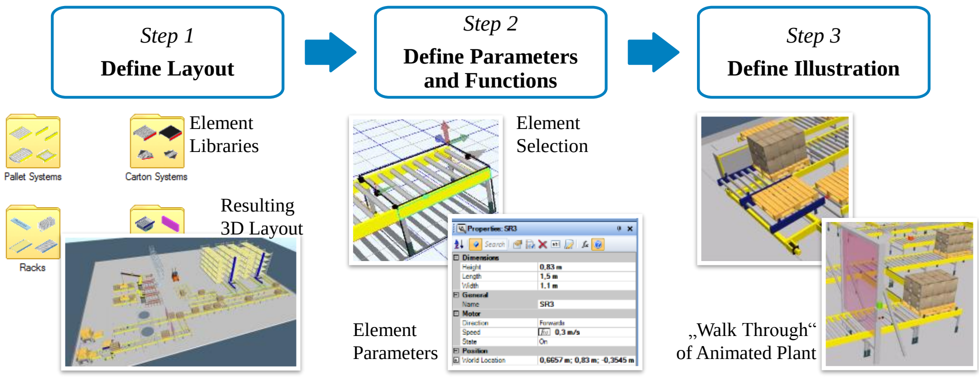


Figure 3. Process steps of defining "Virtual Reality" animated plant model with software Demo3D ®

5. APPLICATION OF SOFTWARE DEMO3D ® IN SCIENTIFIC EDUCATION OF MATERIAL HANDLING

At the University of Miskolc the Institute of Logistics deals with the education of material handling and logistics. The institute has activities on different faculties, in different education fields and specializations *(Figure 4)*. Material handling courses are taught in seven education fields and three different levels (BSc., MSc., PhD.).

Most of the courses (Material handling machines, Material handling machines and systems and Equipment used in logistics) contain the principles and basic information related to handling methods and devices. Most important objective of these courses is to present the structure, operation and characterisation of handling machines for students.

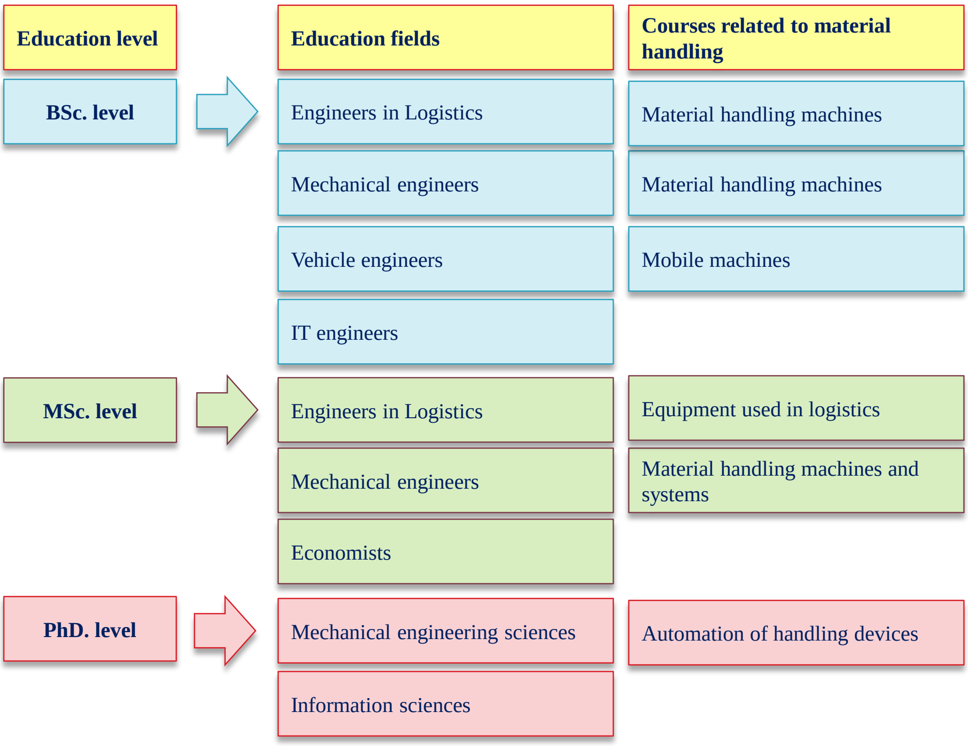


Figure 4. Education structure of LOG

5.1. Education related to material handling

Curricula of the main courses contains similar thematic which involves the topics presented on *Table I*. It can be seen, that the first 5 main topics is the same for all main courses, only the half of the topics are different for the individual subjects.

The first 5 topics contain basic knowledge about material handling and the teaching of them determines the basement for the further studies. It is important that students attended on these courses get sufficient, advanced and understandable knowledge about material handling.

LOG (and its ancestors) is dealing with the education and research related to material handling from 60 years, so the knowledge which is used to develop curricula for the subjects is proved and suitable. Staff of the Institute uses advanced devices to present the planning methods and demonstrate the operation of different machines.

There are two important deficiencies in the education of material handling, one of them is the involving of newest research results into the curricula, other one is the application of new and effective computer devices and software.

Reacting to the first problem, we started a new H2020 project in 2016 (UMi-TWINN), which targeted, among others, to increase the scientific excellence and research capability of the University of Miskolc in the field of logistics. During the project duration, staff of LOG met the researchers of their two high quality scientific project partners (TU Graz, and Fraunhofer IFF) to see their advanced research activities and results. As a result of the UMi-

TWINN project the staff of LOG involved many new and advanced research results into the education materials of the University of Miskolc.

Table I
Main thematic topics of material handling courses of LOG

Topics	Material handling machines	Material handling machines and systems	Equipment used in logistics
1.	*Introduction into the material handling*	*Introduction into the material handling*	*Introduction into the material handling*
2.	*Principles of material handling*	*Principles of material handling*	*Principles of material handling*
3.	*Material handling machines and their elements*	*Material handling machines and their elements*	*Material handling machines and their elements*
4.	*Material handling systems*	*Material handling systems*	*Material handling systems*
5.	*Planning of material handling*	*Planning of material handling*	*Planning of material handling*
6.	*Planning of transport paths*	*Material flow calculations*	*Automation of material handling*
7.	*Planning of mobile material handling machines*	*Equipment selection*	*Automatic handling machines*
8.	*Planning of conveyor systems*	*Process planning*	*Automated handling systems*
9.	*Dynamical characteristics of handling machines*	*Storing systems*	*Maintenance of handling machines*
10.	–	*Automation of material handling*	*Reliability of handling machines*

Related to the second deficiency, we can state that the education materials of LOG contains computer methods and software, however they cannot be used for material handling machines. During the project, staff of ITL presented their computer devices to the Hungarian partners, and University of Miskolc decided to make an education development related to material handling courses using knowledge and devices of the Austrian partner.

5.2. Application of Demo3D ® in the education

As the education of LOG is dealing mainly with the structure and operation of handling machines, it was obvious to use a 3D virtual reality method for the development. Related to *Table I*, main application possibilities of these methods are

- visualisation of handling machines,
- drawing structural elements and their relations,
- demonstrate the operation of machines,
- simulate the operation and structure of handling systems,
- demonstrate the effects of influencing parameters of machines, etc.

Suited to the advantages of it, we used software Demo3D ® to realize the above mentioned tasks. There are many handling machines and solutions in the industry, so at first we selected some important and usually used machine and system versions to present the process and its applicability: conveyors, transfer cars, load lifters, AGV systems, LHD, sorter systems, etc.

To apply Demo3D ® in handling systems, we need to create a transformation procedure, which involves the determination of device parameters, application environment, process steps and details. Main steps of the application procedure are:

1. Definition of the machine/system
2. Description of the structure/elements
3. Description of the operation principles/theories
4. Determination of the industrial environment/application parameters
5. Implementation in Demo3D ®

First step of the procedure is the definition of the machine (or the system), which has to be suited to the handling task you need to realize. Functions, operations (at machines) or tasks of system elements have to be defined during this process step.

Next task is the description of the structure of machines or system elements and the selection of building elements and applicable solutions. For the realization of this step we can use predefined machine elements or connections, or we can build new, specific solutions.

After the description of machine or system details, we can determine the operation parameters of actual solutions, where we can use mathematical principles and theories described in the related literature.

In the knowledge of required mathematical formulas, we can take the effects of industrial environment and application parameters into consideration. In this step, we can fit the machine or system to the real requirement.

Last step of the application procedure is the implementation of the machine or system variation in Demo3D ®. As a result of the procedure we have got a 3D simulation about the machine or the system which can be analysed, observed and tested in simulated operation environment.

5.3. Application scenario

Demonstrating the development procedure we applied it to a complex roller conveyor system, which is used in an industrial environment.

During the definition of the handling system *(Figure 5)*, we selected only roller conveyor elements and palette (box) handling operations.

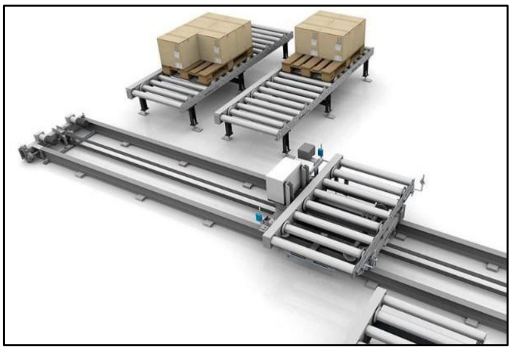
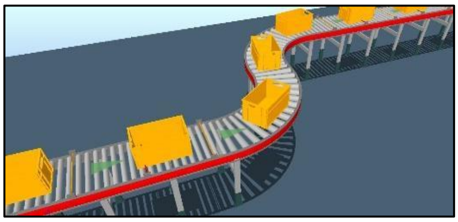
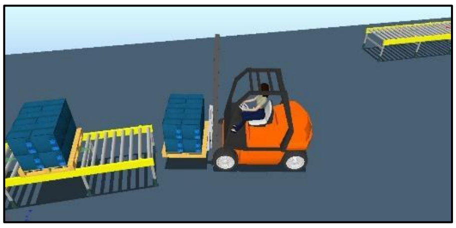


Figure 5. Example for a roller conveyor system

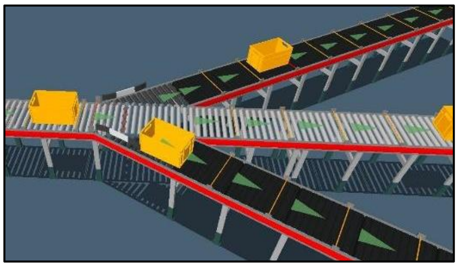
For the transportation of palettes and boxes we can use different section elements, which are defined on *Figure 6* (Demo3D ® elements).



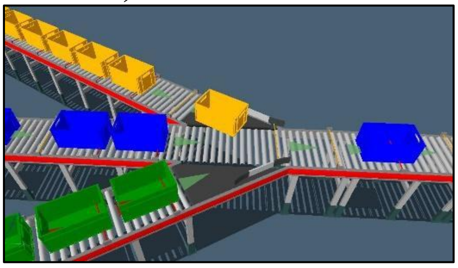
a) Section element



b) Connection element



c) Branching element



d) Merge element

Figure 6. Example for structural elements of roller conveyors

Taking the scientific aspect of the operation into account, we defined the next characteristics for the system:

- floor bound,
- consists of a frame (wheels and drive) and a lifting device,
- mostly used as palette conveyors,
- connects different conveyor systems,
- choice of the lifting device depends on the bordering conveyor system (roller track, chain conveyor etc.).

For the calculation of handling parameters we used the education books of ITL (e. g. [34], [35]).

In the aspect of industrial environment and application parameters we applied the next data (Kardex Mlog):

- function: horizontal transport of loads, load lifting with chain- or roller conveyor or telescopic fork
- output: 180 units/h
- load carrier: palettes, lattice boxes
- load weight: 1,200 kg/lifting device
- driving speed: max. 4 m/s

As a result of our procedure, the implementation in software Demo3D ® can be seen in *Figure 7* (a simple machine) and *8* (a complex system).

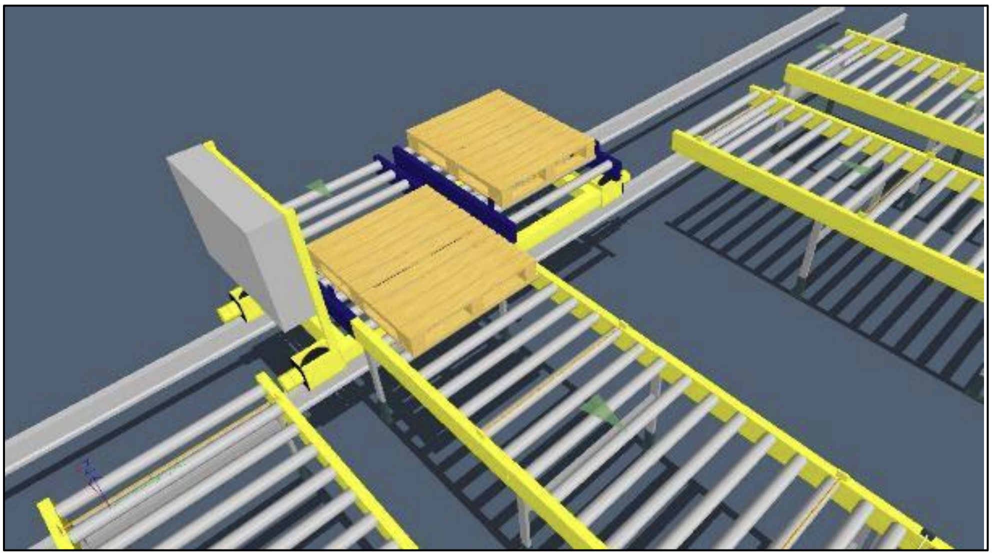


Figure 7. Realization of the machine in Demo3D ®

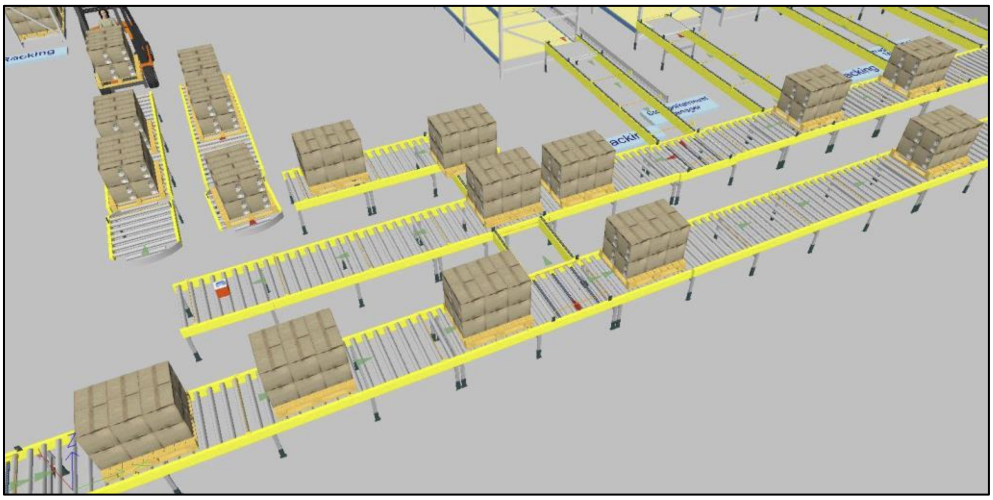


Figure 8. Realization of a complex system in Demo3D ®

5.4. Application possibilities and advantages

As a result of the project UMi-TWINN we developed numerous virtual reality models and animated 3D videos based on best practice studies of logistics industries *(Figure 9)*.

The created logistics systems include:

- warehouse system of a distribution center,
- goods receipt and goods shipment area of a manufacturing company,
- sorting technologies within a parcel distribution center, etc.

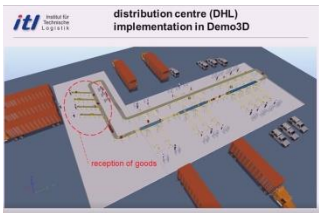
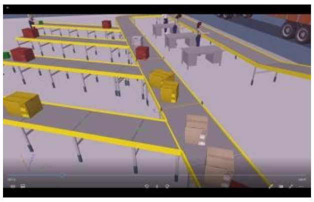
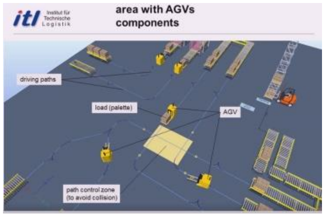
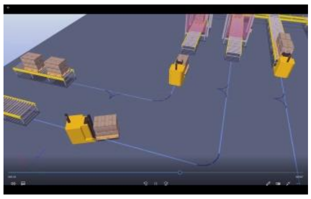
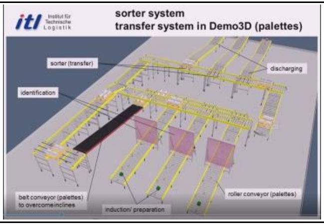
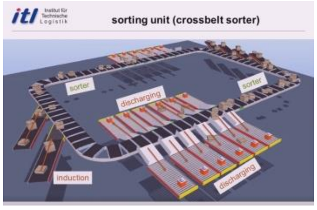
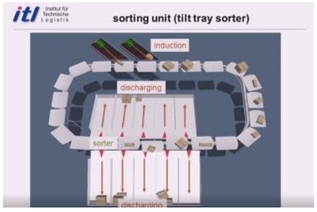
No.	System type	System structure	Demo3D ® simulation
1.	Distribution center		
2.	AGV transport		
3.	Palette sorter system		
4.	Crossbelt sorter system		
5.	Tilt tray sorter system		

Figure 9. Elements of the developed materials

The documents created are an important contribution to support the teaching about intralogistics devices and plants both on LOG and on ITL. The results are also available to students on an internet platform for free download.

The most important application field of the developed videos and sheets is the scientific education of material handling and logistics. They are applied directly in three different courses *(*see *Table I)*, as a part of the curricula: material handling machines and their elements, material handling systems, planning of material handling and automation of material handling.

Main advantages of these materials to show realistic machines and systems, and the effects of changings in any parameters can be directly presented.

Another application of the developed curricula is the direct use of a computer software in the planning process of material handling. Studying the software and its use can help to understand the planning and operation procedure of individual machines and systems.

6. SUMMARY

Scientific education of material handling requires the application of advanced, effective methods. Unfortunately, during the last decades, the University of Miskolc suffered some deficiencies in the teaching of handling machines.

By the help of the project UMi-TWINN, LOG of the University of Miskolc got a chance to develop its teaching materials and devices related to handling machines. During the project, staff of the Institute met the researchers of the TU Graz, and Fraunhofer IFF to see their advanced research activities and results.

Among others, the staff of ITL presented their computer devices to the Hungarian partner. One of the most important result of the project was the application of software Demo3D ® for the education of material handling. The developed examples, videos, sheets and other documentations are directly usable in the teaching curricula of different courses of LOG.

The software Demo3D is not a general solution for planning of material handling machines and processes, but it can help to present the operation of the machines and to demonstrate the effects of the changing of handling parameters, which is very important for the education.

After this starting step, next phase can be the application of software Demo3D ® in other handling processes and planning procedures (e. g. planning of total material flow within a production procedure), which can be used in other logistic courses (e. g. Logistic systems) of LOG.

Another direction of this research process can be the implementation of this software in the research activities of the Institute, which requires further cooperation between the ITL and LOG.

Acknowledgements

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THE CONCEPT OF AUTONOMOUS SYSTEMS IN INDUSTRY 4.0

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Abstract: Recent tendencies – such as the life-cycles of products are shorter while consumers require more complex and more unique final products – poses many challenges to the production. The industrial sector is going through a paradigm shift. The traditional centrally controlled production processes will be replaced by decentralized control, which is built on the self-regulating ability of intelligent machines, products and workpieces that communicate with each other continuously. This new paradigm known as Industry 4.0. This conception is the introduction of digital network-linked intelligent systems, in which machines and products will communicate to one another in order to establish smart factories in which self-regulating production will be established. In this article, at first the essence, main goals and basic elements of Industry 4.0 conception is described. After it the autonomous systems are introduced which are based on multi agent systems. These systems include the collaborating robots via artificial intelligence which is an essential element of Industry 4.0.

Keywords: *Industry 4.0, Cooperating robots, Artificial intelligence*

1. INTRODUCTION

Industry 4.0 conception means the upcoming 4th industrial revolution. According to the theory of the conception, the 1st industrial revolution was the mechanization characterized by the appearance of the steam engine *(Figure 1)*. The 2nd industrial revolution was the mass production through assembly lines on the base of the electricity. The 3rd industrial revolution was the automated production by application of industrial robots [1].

The 4th industrial revolution means the age of the application of intelligent manufacturing robots. In this conception the products control their own production, since these products and components communicate with the machines and equipment by unique product codes during their production. Smart factories will be self-regulating and optimize their own operation. Consequently, it means that virtual and actual reality merges together during the production.

In the first part of the article the characteristics, main goals and pillars of Industry 4.0 conception is described. In the second part of the paper the autonomous systems are introduced which are based on multi agent systems. These systems include the collaborating intelligent robots via artificial intelligence which is an essential pillar of Industry 4.0 conception.

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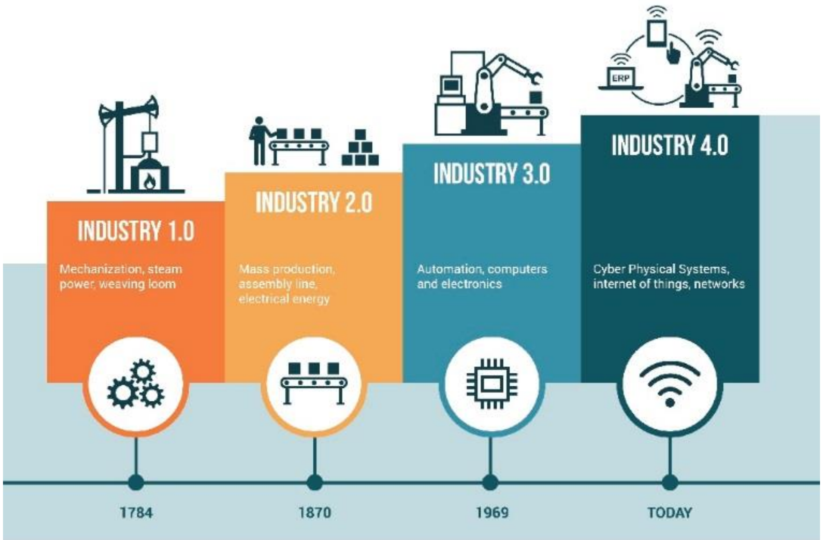

Figure 1. Stages of industrial development [2]

2. CHARACTERISTICS AND GOALS OF INDUSTRY 4.0 CONCEPTION

The essence of Industry 4.0 conception is the introduction of network-linked intelligent systems, which realize self-regulating production: people, machines, tools and products will communicate with each other continuously [3, 4]. Products control their own production; the production scheduling will be controlled by the communicating products.

In smart factories everything is working in interaction between the products and the machines, linked in a network itself connected to the digital supply chain, based on information and communication technologies, sensors, software tools, using the highest performance devices in order to transform industry into an interconnected global system [5].

New technologies appear such as digitization in order to provide continuous communication between machines, systems and products. The aim of the conception is to make factories smarter and to create a digital platform, which brings together the main tools: Sensors, Internet of things, Big data, Cloud computing, Collaborating robots, Artificial intelligence etc. [6].

Industry 4.0 conception is the origin of strategic project of the German government, that was introduced at the Hanover Fair in 2011 [7], to support the digital revolution of the global industry. Recently this conception is widely used not only in Europe but all over the world.

The 5 main elements of the digital networked production according to the conception can be defined by the following:

1. digital workpieces,
2. intelligent machines,
3. vertical network connection,
4. horizontal network connection,
5. smart workpieces.

The essential goals of Industry 4.0 conception are the following:

- to create smart factories,
- to optimize the production which increase productivity,

- to establish more efficient, more flexible, and more customer-oriented production,
- to improve efficiency by automation of processes,
- to maximize the utilization of human- and machine resources,
- to save costs and reduce wastes and lead times,
- to adapt to the changing market demands more effectively,
- to create new opportunities and business models.

The results of application of the conception:

- physical systems will be digitized,
- customers will be satisfied who demand more complex and unique products in small quantities,
- traditional centrally controlled and monitored production processes will be replaced by decentralized controlling,
- factories will be self-regulating which optimize their own operation,
- productivity will be improved,
- fast solutions can be provided in case of production problems and abnormal operations.

Industry 4.0 represents a globally interconnected world defined by digitization of economic and production processes [8].

The Boston Consulting Group has identified the fundamentals of Industry 4.0 by nine technological pillars [9] *(Figure 2)*:

1. **Autonomous robots**. Industrial robots are becoming more autonomous and cooperative. The intelligent robots can interact with one another in order to improve productivity and product quality. These machines can achieve more complex tasks and manage unexpected problems [10].
2. **Horizontal and Vertical system integration**. Horizontal integration of system elements aims to optimize the operation of the whole supply chain by connecting all members of the value chain (e. g. suppliers, manufacturers, service providers, customers). Vertical integration aims to optimize the reconfiguration of production processes by connecting Cyber Physical Systems (sensors, actuators etc.).
3. **Industrial Internet of Things (IoT).** Industrial IoT allows devices to communicate and interact with one another. It is a network connection and data exchange of objects, e. g. products, machines, equipment, vehicles or other incorporated devices, so the devices can be used more efficiently and economically. System collects and shares huge amounts of data inside the digital supply chain network that ensures the exchange of information between the system elements.
4. **Simulation**. Simulation of processes is essential during product design, production planning and in case of material flow processes, or in modeling of unexpected stochastic events. In the future simulation will be used more often in plant operations as well. Simulation is a tool for providing real-time data to observe the physical world in a virtual surrounding, which can include machines, tools, products and humans. It is an effective tool to optimize the production and maximize the utilization of resources.
5. **Additive manufacturing**. Additive Manufacturing is a terminology to describe the technologies that build 3D objects by adding layer upon layer of a given material (3D printing). This technology offers the possibility of manufacturing of more complex components which is unachievable by other techniques. The technology provides

higher flexibility and efficiency of manufacturing of smaller batches and more customized final products.

6. **Cloud computing**. The cloud offers an unlimited computing power to receive, store and analyze Big Data needed for the optimal operation of systems. The stored information and services can be available at any given place and device via internet [12]. It allows all system elements to synchronize their activities and work on shared data and services simultaneously in real time.
7. **Augmented reality**. Augmented reality provides the possibility of visualization by transforming the real environment to a virtual environment [13]. The information relating to the surrounding real world of the user becomes interactive and digitally manipulable by the application of augmented reality technology.
8. **Big data**. Intelligent network-like systems require huge, almost unmanageable amount of information. This data set is called big data. According to the IoT principles, the collection and evaluation of this data set coming from many different sources will become essential for real-time decision-making. The analysis of this huge amount of information will optimize the operation of manufacturing systems.
9. **Cybersecurity**. The huge amount of data shared on network should be protected. Cybersecurity includes technologies and processes which are designed to protect systems, networks and data from cyber-attacks.

Figure 2. Pillars of Industry 4.0 [11]

3. ARTIFICIAL INTELLIGENCE BASED ROBOT COLLABORATION

This age is the age of emerging intelligence, in every aspect of life. The questions of human-robot and robot-robot cooperation become actual for today [14]. While this new industrial age also has effects on social-level, industrial applications are in the forefront of our article and require deeper analysis. Our research is carried out in accordance with the Industry 4.0 concept, in which unmanned production and the development of smart factories with intensive and wide use of artificial intelligence in many aspects are aimed at automating of production forces on an unprecedented level. In the technical realization the two central AI-related disciplines are Multi-Agent Systems and Distributed AI. In addition to these essential information technologies the biologically inspired new ideas and methods are also need mentioning.

Typically, in this regard an autonomous system is based on a multi-agent system which is endowed by artificial intelligence, this concept aims to create intelligent machines collaborating together to build a flexible environment [14] as shown in *Figure 3* which represents collaborating and cooperating manipulator arms in industry. These industrial innovations are in the focus of today researches, some achievements and human-related safety requirements are documented in the ISO 10218-1 Robot, ISO 10218-2 Robot system/cell and in the ISO/TS 15066 Collaborative Robots standards [15].

Figure 3. Collaborating robots

3.1. Multi agent systems (MAS)

The agents can detect the signals of the environment and react to them. So people, machines, computers, etc. can be agents and can cooperate and interact each other. In the industry, these agents represent machines, controllers, robots which use a common language to provide cohabitation and collective work. To design a multi-agent system, we must know the model of each agent that will come into action and define their environment and their interactions and the essential objectives to achieve [16]. A borderline can be set up between reactive and cognitive agents: in opposition to the simple reflexive reactive agents the cognitive agents are can form plans to achieve their goals. Based on [17], two types of communication among these agents can be defined:

1. **Implicit communication**. In this method the agent that uses various sensors receives information about other agents acting in the same system through the appropriate environment. This type of communication can be divided into passive or active

implicit types. The passive means that the agents communicate via their environment, while the active use sensing to get the information.

2. **Explicit communication**. In this case there is direct communication among agents for information sending and receiving, which can be done in the form of unicast or intentional broadcast messages usually through a dedicated communication module. This explicit communication helps to realize diverse coordination methods among agents.

Ought to this explicit communication the agents can realize different advantageous strategies. Meanwhile they alternate the active and passive roles and communicate with messages according to the common strategies introduced by the following definitions [18, 19]:

- **Coordination strategy** of the agent means that they make a plan for longer period that determines the arrangement and order of the tasks to be executed together. The goal of the coordination is to unite the resources and forces to achieve the common goal effectively. Agents use coordination protocols to define the requirements and actions that are needed to fulfill the common goal.
- **Cooperation strategy** of the agents aims of solving such larger or complex tasks that are too large for an individual agent. The strategy consists of the optimal decomposition of the larger task into subtasks and has to take into the capabilities and possibilities of the cooperating agents.
- **Negotiation strategy** of agents is necessary when the agents have different goals but they would like to achieve a mutually advantageous solution. The two components of this strategy are:
  - **Negotiation language** helps to perform the communication and to transfer the information analyzing the semantic of the content moreover defines the role of communication primitives in the used protocols,
  - **Process of negotiation** determines the behavior of the agents during negotiation.

3.2. Artificial Intelligence (AI)

This discipline is a prospect to the future. Includes many human intelligence inspired techniques that can substitute human beings in their mental and cognitive activity [20]. Methods of AI used by the autonomous systems to solve high level tasks and unforeseen situations. These methods implemented in machines, IoT components and in manipulator-like and humanoid robots. The AI phenomenon can’t be separate from learning and from adaptation of the agents to their environment [21]. The AI agent models the necessary part of the world using different knowledge representation methods, like symbolic logic, semantic networks and frames, or artificial neural networks. For the realization of the intelligence different kinds of cognitive methods applied, like learning, concept formalization, reasoning, searching, machine vision and even communication language.

3.2.1. Distributed Artificial Intelligence (DAI)

This work deployment method can be used effectively when the tasks are distributable but every of them needs intelligent solution. The DAI structure includes agent cooperation and communication among intelligent agents [16]. DAI has an overlapping with MAS concept. The relation among software systems based on agent technologies like DAI, MAS and mobile agents (MA) is shown in *Figure 4*.

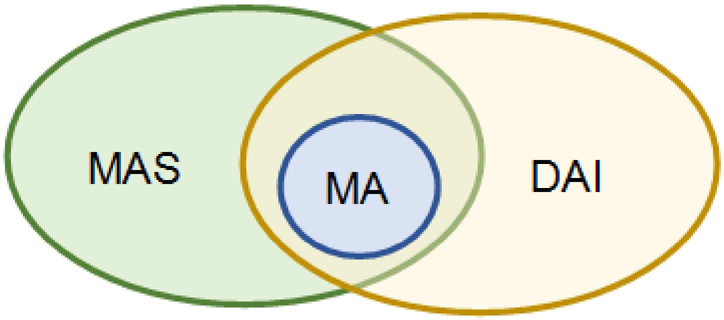

Figure 4. Relation among software systems based on agent technologies

3.2.2. Role of Multi Agent Systems in Industry 4.0

Using a MRS in Smart factory can have several potential advantages over a single-agent system such as robot [17]:

- A MRS has a better spatial distribution.
- A MRS can achieve better overall system performance. The performance metrics could be the total time required to complete a task or the energy consumption of the robots [22].
- A MRS introduces robustness that can benefit from data fusion and information sharing among the robots, and fault-tolerance that can benefit from information redundancy. For example, multiple robots can localize themselves more efficiently if they exchange information about their position whenever they sense each other [23].
- A MRS can have a lower cost. Using a number of simple robots can be simpler (to program), cheaper (to build) than using a single powerful robot (that is complex and expensive) to accomplish a task.
- A MRS can exhibit better system reliability, flexibility, scalability and versatility. Robots with diverse abilities can be combined together to deal with complex task, and one or several robots may fail without affecting the task completion [24].

3.2.3. Applied AI Methods in Intelligent Robot Behavior

The intelligence coming from different AI methods can be used in standalone robots to help its working, like Swarm intelligence based joint position optimization, or use of feedforward Artificial Neural Network for solving the inverse kinematical problem when the determination of joint functions depending from the necessary path of the robot hand is needed. In the future robots the use of AI will not be limited for solving such motion-oriented tasks but can be imagined in cognitive processes like sensing, learning, problem solving, machine vision and using language for communication [25]. These high level cognitive functions that may evolve to machine problem solving, play important role in robot coordination, cooperation, evaluation and collaboration [18, 26]. The next table systematize the well-known AI methods that can be used in different scenarios of collective behavior of robots *(*see *Table I).*

Table I
AI methods and their possible use in robots collaboration

AI method	**Role in collective robots behavior**
Rule and symbolic logic based systems [28]	Knowledge representation, cooperative decision making
Fuzzy Logic [29]	Flexible common answering on environment changes, decision making
Machine vision and sensing [30]	Getting visual information of the objects and location and actions of other robots, help self- and cooperative localization Possibility for detection of malfunctions Serves as information source for – collective – learning
Search methods	Cooperative decision making and optimization
Evolutionary and genetic algorithm [31]	Robot group efficiency and quality improvement
Swarm intelligence [32, 33]: – Ant colony optimization – Particle swarm optimization – Shortest route finding	Creation of complex structures System self-reorganization Collective behavior planning and directing: – Collective optimization – Resources integration – Common goal realization
Artificial Neural Networks [30]	Process control and abnormality detection Learning new features of the environment and new scenarios through clustering Cooperative decision making

3.2.4. The potential advantages of AI to many solutions in practice

Thanks to recent advances in artificial intelligence (AI), we are now at the cusp of a major transformation in business, many leading companies have begun to embrace a new view of business processes as more fluid and adaptive. In essence, they are moving beyond rigid assembly lines toward the idea of organic teams that partner of humans with advanced AI systems. This collaboration between workers and smart machines is leading to the reinvention of many traditional processes. As BMW and Mercedes-Benz have experienced, rigid assembly lines are giving way to flexible teams of employees working closely alongside robots. Moreover, these novel types of teams can continuously adapt on the fly to new data and market conditions [34]. They are enabling companies to actually reimagine various work processes.

Contrast the traditional assembly line with a factory where robots are much smaller and more flexible, able to work alongside humans. This is a factory, where those robots and other types of machinery are using embedded sensors and sophisticated AI algorithms. Unlike earlier generations of industrial robotics which were typically bulky, unintelligent, and somewhat dangerous pieces of machinery these new types of collaborative robots are equipped with the ability to sense their environment, comprehend, act, and learn, thanks to machine-learning software and other related AI technologies. All this then enables the work processes to be self-adapting, with fixed assembly lines giving way to flexible human-machine teams that can be put together on the fly.

Now, in order to fulfil customized orders and handle fluctuations in demand, employees can partner with robots to perform new tasks without having to manually overhaul any processes or manufacturing steps. Those changes are baked into the system and are performed automatically. The advances are not just in manufacturing. AI systems are being integrated across all departments, everything from sales and marketing to customer service and production.

3.2.5. Implementation of AI at Companies

For a century, factory floors have been at the leading edge in robotic automation. From conveyor belts to robotic arms with AI-infused operations systems, the factory is getting smarter every day [27].

- Hitachi is using AI to analyze big data and workers' routines to inform its robots, which deliver instructions to employees to meet real-time fluctuating demand and on-site kaizen objectives. In a pilot, the company observed an 8 percent productivity improvement in logistics tasks.
- At Siemens, armies of spider-styled 3-D printed robots use AI to communicate and collaborate to build things in the company's Princeton lab. Each bot is equipped with vision sensors and laser scanners. In aggregate, they join forces to manufacture on the go.
- At Inertia Switch, robotic intelligence and sensor fusion enable robot-human collaboration. The manufacturing firm uses Universal Robotics' robots, which can learn tasks on the go and can flexibly move between tasks, making them handy helpers to humans on the factory floor.

4. SUMMARY

The content of the paper was divided into two parts. In the first the concept of Industry 4.0 automatization trend was introduced by introducing its main goals and its expectable benefits, then the components that bring together the nine pillars of this industrial revolution were analyzed, which can be defined as a cyberspace that controls everything from demand to product design. This evolution includes intelligent automation and integration of digital technologies like 3D printer, cloud computing, augmented reality, Internet of Things etc.

Secondly it discussed the autonomous systems that represent a useful factor for successful digital transformation of the manufacturing and create a smart factory, known as multi-agent systems, in the industrial field these agents can be manipulators arms, sensors, controllers endowed by artificial intelligence, this approach is one of the technologies supported by Industry 4.0, it regroups different fields of research such as collaboration between these agents based on the communication among them and their environment and the principle of collective work led by swarm intelligence. The role of AI in the environment of collaborating robots was described in a table covering all the important main AI fields.

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