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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 18th century, in which the motorized machines were appeared and spread. The next step was the starting of mass production in the beginning of the 20th century, where the effective handling became the most important objective.

At the end of the 20th 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.

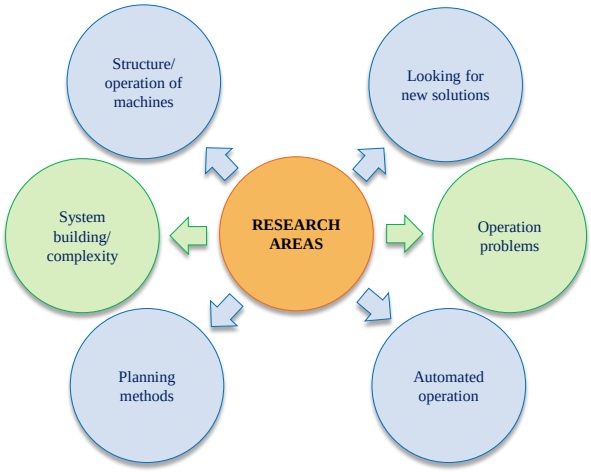

Figure 1. Main research areas of material handling

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].

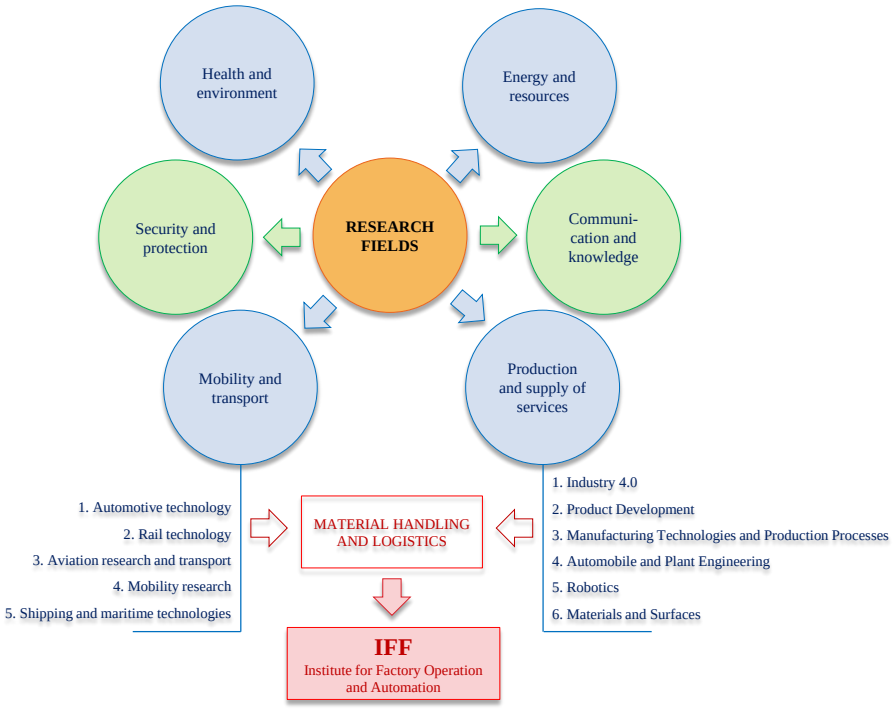

Figure 2. Role of IFF in the research activities of the Fraunhofer Foundation

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.

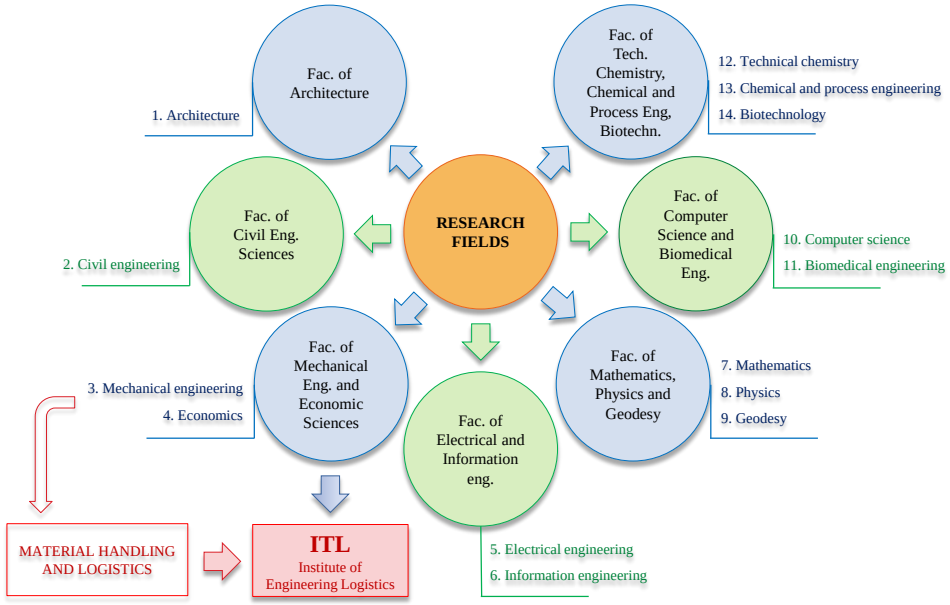

Figure 3. Role of ITL in the research activities of the TU Graz

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 1200 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.

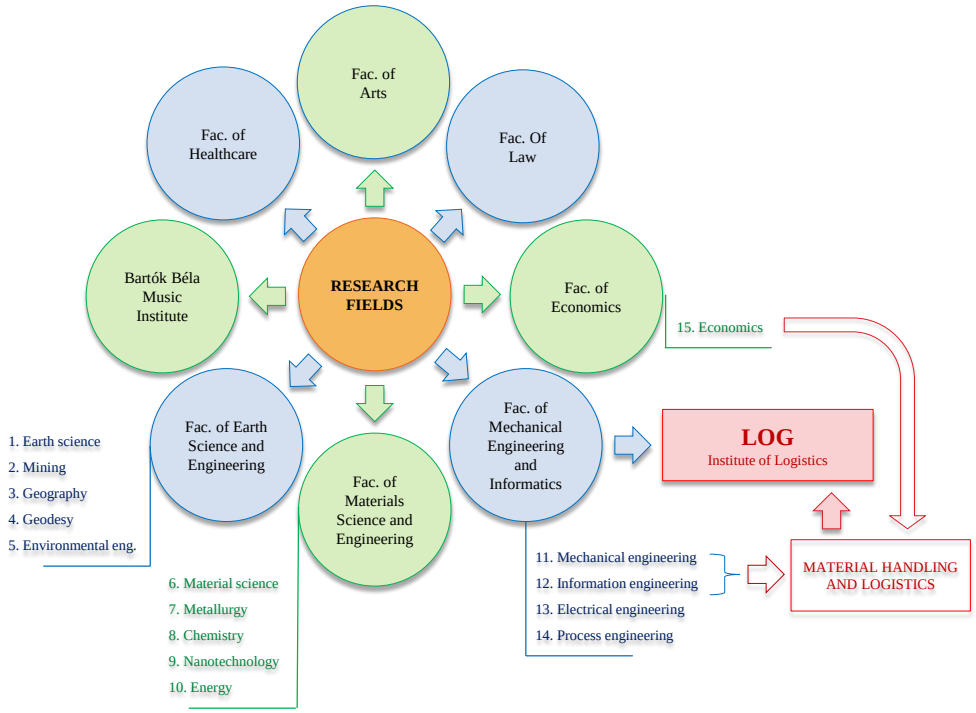

Figure 4. Role of LOG in the industrial research activities of the University of Miskolc

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).

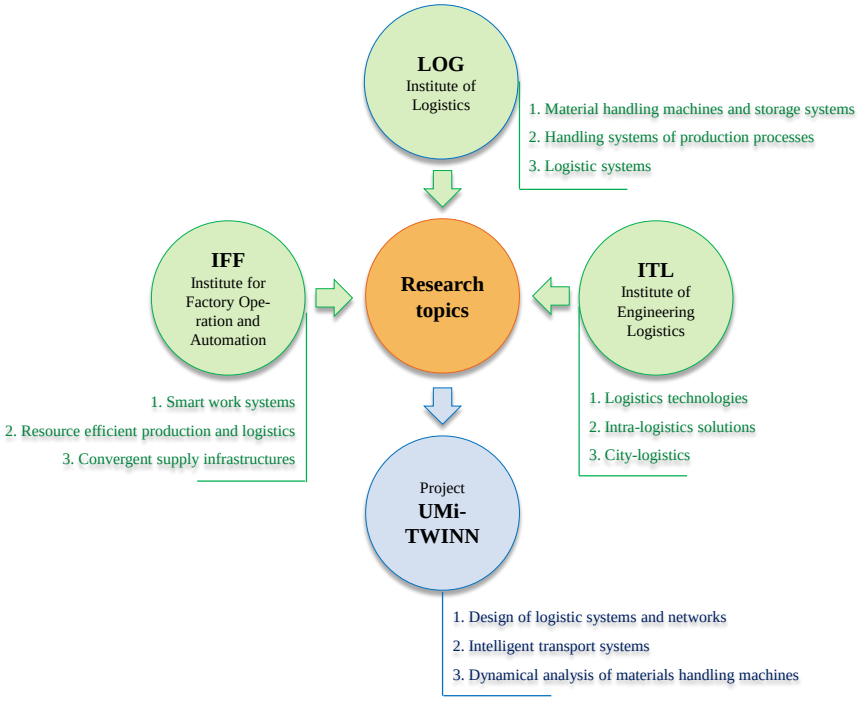

Figure 5. Topic searching for the project UMi-TWINN

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.

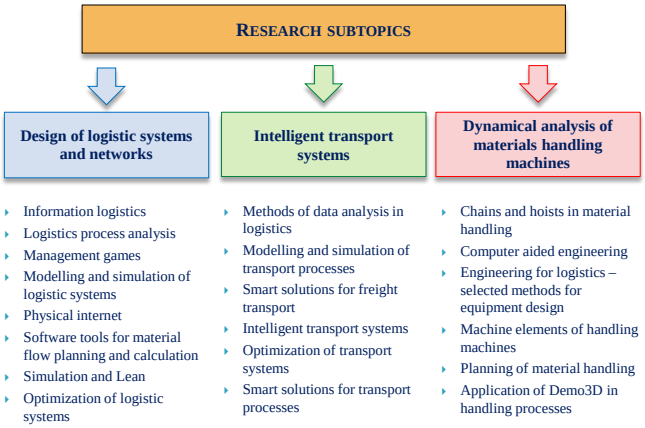

Figure 6. Topics trained and published in UMi-TWINN

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).

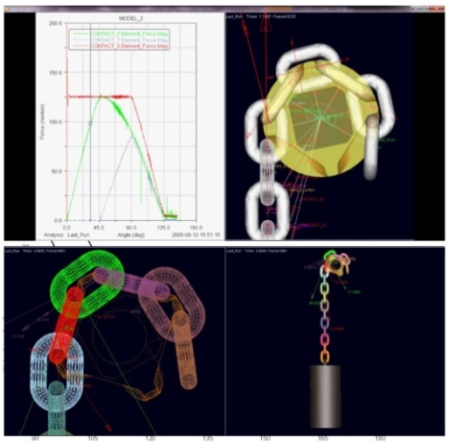

Figure 7. Analysis of chain elements in hoist
source: ITL

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).

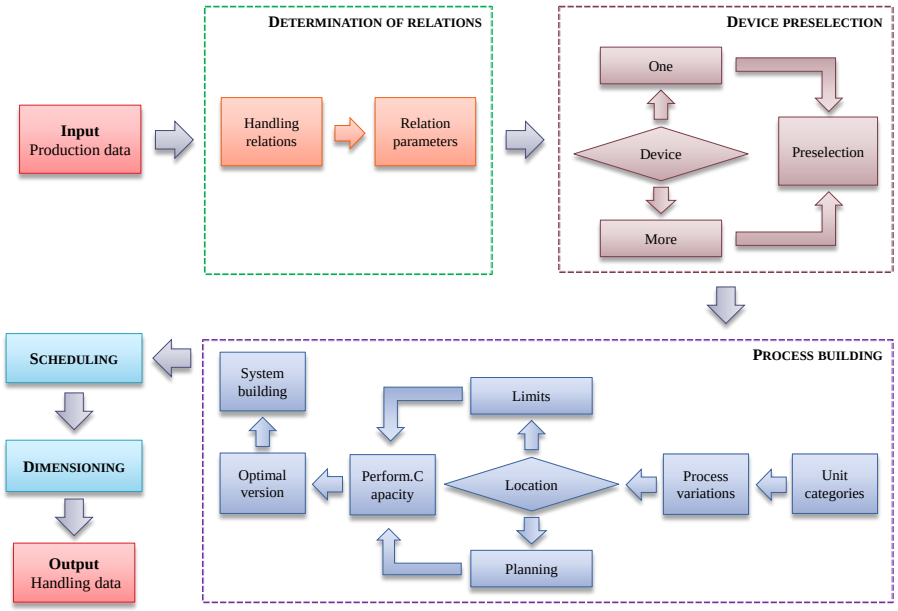

Figure 8. Algorithm of the process-based planning [29]

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).

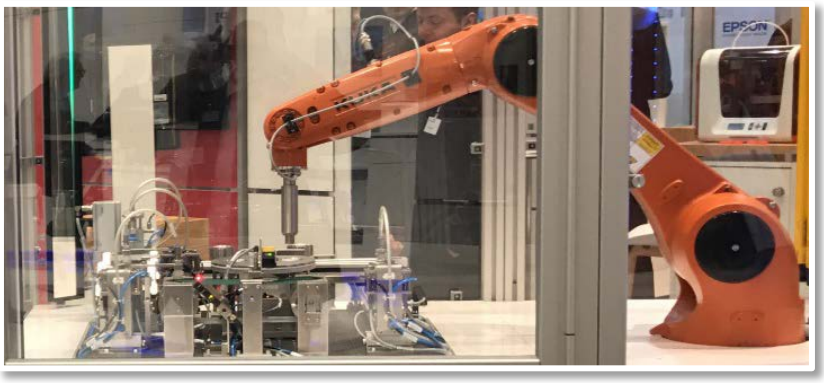

Figure 10. Virtual Numerical Control Environment VINCENT
source: Fraunhofer IFF

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.

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References

[1] Taghaddos, H., Hermann, U. & Abbasi, A. (2018) Automated Crane Planning and Optimization for modular construction. *Automation in Construction 95*, 219-232. https://doi.org/10.1016/j.autcon.2018.07.009

[2] Masaki, M. S., Zhang, L. & Xia, X. (2018) A design approach for multiple drive belt conveyors minimizing life cycle costs. *Journal of Cleaner Production 201*, 526-541. https://doi.org/10.1016/j.jclepro.2018.08.040

[3] Apple, J. M. (1977). *Material handling system design*. New York: John Wiley & Sons.

[4] Modrak, V. & Marton, D. (2012) Modelling and Complexity Assessment of Assembly Supply Chain Systems. *Procedia Engineering 48*, 428-435. https://doi.org/10.1016/j.proeng.2012.09.536

[5] Felföldi, L. (ed.) (1975) *Materials handling handbook (in Hungarian).* Budapest: Engineering Press

[6] Cselényi, J. & Illés, B. (Eds.). (2006). *Design and control of material flow systems I. (in Hungarian).* Miskolc: University Press.

[7] Halim, N. H. A., Yusuf, N., Jaafar, R., Jaffar, A., Kaseh, N. A. & Azira, N. N. (2015) Effective Material Handling System for JIT Automotive Production Line. *Procedia Manufacturing 2*, 251-257. https://doi.org/10.1016/j.promfg.2015.07.044

[8] Hichri, B., Fauroux, J. C., Adouane, L. Doroftei, I. & Mezouar, Y. (2019) Design of cooperative mobile robots for co-manipulation and transportation tasks. *Robotics and Computer-Integrated Manufacturing 57*, 412-421. https://doi.org/10.1016/j.rcim.2019.01.002

[9] Björnsson, A., Jonsson, M. & Johansen, K. (2018) Automated material handling in composite manufacturing using pick-and-place systems – a review. *Robotics and Computer-Integrated Manufacturing 51*, 222-229. https://doi.org/10.1016/j.rcim.2017.12.003

[10] Grincova, A., Andrejiova, M., Marasova, D. & Khouri, S. (2019) Measurement and determination of the absorbed impact energy for conveyor belts of various structures under impact loading. *Measurement 131*, 362-371. https://doi.org/10.1016/j.measurement.2018.09.003

[11] Keränen, T. M., Karimäki, H., Viitakangas, J., Vallet, J., Ihonen, J., Hyötylä, P., Uusalo, H. & Tingelöf, T. (2011) Development of integrated fuel cell hybrid power source for electric forklift. *Journal of Power Sources 196*(21), 9058-9068. https://doi.org/10.1016/j.jpowsour.2011.01.025

[12] Korponai, J., Bányai Á., Illés B. (2017). The effect of the safety stock on the occurrence probability of the stock shortage. *Management and production engineering review 8*(1), 69-77. https://doi.org/10.1515/mper-2017-0008

[13] Illés, B. & Telek, P. (2017) Results of the UMI-TWINN Project During Months 1-15. *In: Kékesi, T. (ed.) CD Proceedings of MultiScience - XXXI. microCAD International*

Multidisciplinary Scientific Conference. Paper: C1. 8, University of Miskolc, Hungary, https://doi.org/10.26649/musci.2017.049
[14] Fraunhofer Foundation. Retrieved from http://www.fraunhofer.de
[15] Fraunhofer Institute for Factory Operation and Automation. Retrieved from https://www.iff.fraunhofer.de/
[16] Graz University of Technology. Retrieved from https://www.tugraz.at/en/home/
[17] Institute of Engineering Logistics of Graz University of Technology. Retrieved from https://www.tugraz.at/institute/itl/home/
[18] University of Miskolc. Retrieved from http://www.uni-miskolc.hu/
[19] Institute of Logistics of University of Miskolc. Retrieved from http://geik.uni-miskolc.hu/intezetek/LOG/index.php
[20] Bányai, T. (2012). Direct shipment vs. cross docking. *Advanced Logistic Systems: Theory and Practice 6*(1), 83-88.
[21] Veres P., Bányai T. & Illés B. (2017). Intelligent transportation systems to support production logistics. *Lecture Notes in Mechanical Engineering F12*, 245-256. https://doi.org/10.1007/978-3-319-51189-4_24
[22] Cibicik, A. & Egeland, O. (2019). Dynamic modelling and force analysis of a knuckle boom crane using screw theory. *Mechanism and Machine Theory, 133,* 179-194. https://doi.org/10.1016/j.mechmachtheory.2018.10.019
[23] Telek, P. (2016) Design Problems of Conveyors. *In: Kékesi, T. (ed.) CD Proceedings of the MultiScience - XXX. microCAD International Multidisciplinary Scientific Conference*. Paper: C1. 10, University of Miskolc, Hungary, https://doi.org/10.26649/musci.2016.038
[24] Landschützer, C. & Jodin, D. (2016) Engineering for logistics. *Proceedings in manufacturing systems 11*(2), 63-70.
[25] Telek, P. (2018) Effects of Logistic Processes to the Maintenance Time. *Research Papers Faculty of Materials Science and Technology Slovak University of Technology, 26*(42), 135-143. De Gruyter, https://doi.org/10.2478/rput-2018-0016
[26] Ortner-Pichler, A. & Landschützer, C. (2017) Improving geometry manipulation capabilities of Knowledge-Based Engineering applications by the versatile integration of 3D-CAD systems. *In: Kékesi, T. (ed.) CD Proceedings of the MultiScience - XXXI. microCAD International Multidisciplinary Scientific Conference.* Paper: C1. 3, University of Miskolc, Hungary, https://doi.org/10.26649/musci.2017.044
[27] Weigert, D., Aurich, P. & Schenk, M. (2017) Implementation of an automated exchange system for construction, simulation, and visualization tools. *In: Kékesi, T. (ed.) CD Proceedings of the MultiScience - XXXI. microCAD International Multidisciplinary Scientific Conference*. Paper: C1. 4, University of Miskolc, Hungary, https://doi.org/10.26649/musci.2017.045
[28] Telek, P. & Landschützer, C. (2017). Complexity analysis of material handling design processes. *Advanced Logistic Systems –Theory and Practice, 11*(1), 61-76.
[29] Telek, P. (2018) Process-based planning of material handling in manufacturing systems. *IOP Conf. Series: Materials Science and Engineering 448*, 012018, https://doi.org/10.1088/1757-899X/448/1/012018
[30] Telek, P. (2018) Advanced planning methods of material handling. *Journal of Machine Manufacturing 57*(1-2), 70-78.
[31] Telek, P. (2017) Computer method for the determination of materials handling relations. *In: Kékesi, T. (ed.) CD Proceedings of the MultiScience - XXXI. microCAD International Multidisciplinary Scientific Conference.* Paper: C1. 5, University of Miskolc, Hungary, https://doi.org/10.26649/musci.2017.046
[32] Telek, P. (2016). Material flow relations in the design process of materials handling. *Advanced Logistic Systems –Theory and Practice, 10*(1), 53-64.
[33] Kovács, Gy. & Kostal, P. (2016) Mathematical description of material flow. Materials Science and Technology (Slovakia) *1*, 14-21.

[34] Telek, P. (2016). Computer algorithm for determination of material flow relations. *Advanced Logistic Systems –Theory and Practice, 10*(2), 71-78.

[35] Dobos, P., Tamás, P., Illés, B. & Balogh, R. (2018) Application possibilities of the Big Data concept in Industry 4.0. *IOP Conf. Series: Materials Science and Engineering 448*, 012011, https://doi.org/10.1088/1757-899X/448/1/012011

[36] Poenicke, O., Kirch, M., Richter, K., Schmid, F. & Telek, P. (2017) Wearable solutions for efficient manual logistics processes - RFID Wristband and Smart-Glasses. *In: Landschützer, C. & Ehrentraut, F. (ed.) 4th International Physical Internet Conference*, Graz, Ausztria, 160-169.

[37] Illés, B. & Tamás, P. (2016) Smart logistics in the production process (in Hungarian). *Journal of Machine Manufacturing 55*(2), 51-56. ISSN 0016-8580

[38] Benotsmane, R., Dudás, L. & Kovács, Gy. (2018) Collaborating robots in Industry 4.0 conception. *IOP Conf. Series: Materials Science and Engineering 448*, 012023. https://doi:10.1088/1757-899X/448/1/01202

[39] Telek, P. & Bányai, T. (2018) Advanced Materials Handling Processes and Devices in the Automotive Industry. In: Jármai K., Bolló B. (eds) Vehicle and Automotive Engineering 2. VAE 2018. *Lecture Notes in Mechanical Engineering*. 315-328. Springer, Cham, https://doi.org/10.1007/978-3-319-75677-6_26

[40] Kota, L. (2018) Artifical intelligence in Logistics: Applications and algorithms. *Journal of Machine Manufacturing 57*(1-2), 33-41

[41] Bányai, T. et al. (2018). Smart Scheduling: An Integrated First Mile and Last Mile Supply Approach. *Complexity*, 5180156, https://doi.org/10.1155/2018/5180156