Advanced Logistic Systems – Theory and Practice, 13(2), 29-44, https://doi.org/10.32971/als.2020.003

PLANNING OF MATERIAL HANDLING – LITERATURE REVIEW

PÉTER TELEK[1]-ÁKOS CSERVENÁK[2]

Abstract: Nowadays, there are many well proved, effective processes to solve planning tasks in the field of material handling used advanced calculations forms and software. Unfortunately, most of them are used for individual tasks, so the applicability of their results is limited. The Institute of Logistics of the University of Miskolc has been working on integrated planning of handling machines for decades, where the individual planning tasks have to be solved together in a complex process. The main aim of this paper is to give an overview about the state of the art of the planning of material handling, based on a literature review of the Science Direct publication database. As a result of this research we can determine some new directions for the planning of material handling.
Keywords: material handling, planning process, literature review, research directions

1. INTRODUCTION

During the hundred-year history of the industrial material handling, the applied planning methods and devices have been changed dramatically, but the planning tasks and principles are even similar to their ancestors.

Nowadays, there are many well proved, effective processes to solve planning tasks used advanced calculations forms and software [1]. Main problem of them is that most of them are used for individual tasks, so the applicability of their results is limited and related only to one certain task (e.g. facility location, structure dimensioning).

The Institute of Logistics of the University of Miskolc has been working on integrated planning of handling machines for decades, where the individual planning tasks have to be solved together in a complex process.

One of our main objectives is to determine the place of the Institute of Logistics in the international research sphere and to find new development directions related to the material handling. To reach this target, in this paper, we give an overview about the state of the art of the planning of material handling, based on a literature review of the Science Direct publication database.

2. RESEARCHES RELATED TO MATERIAL HANDLING

During material handling different goods, products, elements or living objects are moved for fulfilling different requirements (industrial, service, personal, etc.). To realize the appearing tasks, we can use many solutions (devices, methods, etc.) suited to the different needs, conditions and limitations. The development of the machines, equipment and methods used for the handling processes requires intensive research activities.

[1] PhD, University of Miskolc, Institute of Logistics, Hungary
alttelek@uni-miskolc.hu
[2] MSc, University of Miskolc, Institute of Logistics, Hungary
cservenak.akos@uni-miskolc.hu

2.1. Research methodology

In the 21st century, the most important platforms for publishing research results are the international scientific journals. The best journals are indexed in different database (Scopus, Science Direct, Web of Science, etc.), where the papers can be browsed and read easily.

In our paper, we analyse and summarise publications indexed in the Science Direct database, which is an easily available and wide platform. In the first step of the research, we give a statistical overview about thousands of related publications based on the most important characterisations, then we analyse the papers related to the planning steps of material handling.

2.2. Researches related to material handling in the Science Direct database

In the last decades of the nineteenth century, material handling stepped over the border of the production processes, integrated many new fields, which required new approaches and resulted a new definition: logistics. Logistics integrates the intern and extern handling processes and all elements of the supply chain, involves many methods, devices and procedures.

During this research, we are dealing with only the publications related to the industrial material handling, so we analyse only the classical handling topics and equipment, and we leave those areas where the research directions focus to the technology aspects (excavators, mining machines, etc.).

Until September 2019, we found 1758 word matches in the titles of research papers in the Science Direct database related to the classical material handling fields (Figure 1).

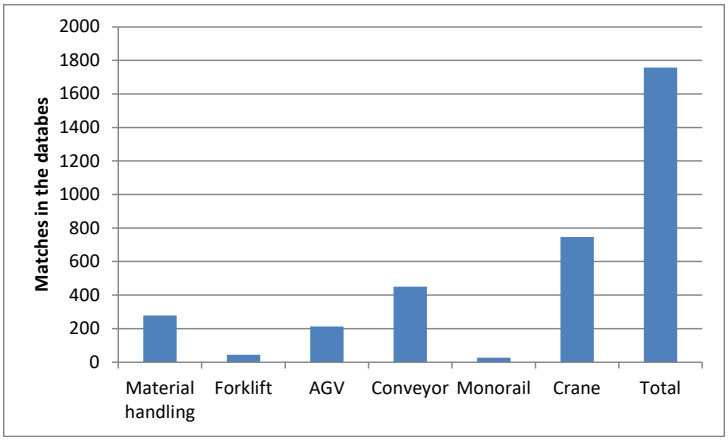

Figure 1. Distribution of the matches related to material handling in Science Direct (2019)

To determinate the thematic distribution of the publications, we defined 5 different groups related to the research categories described in [2]:

1. Structure
2. Operation
3. System
4. Planning
5. Automation

Structure category contains publications related to the planning, development and application of machine elements and structural building of handling machines. **Operation** category contains publications related to the operation characteristics, problems and control of the material handling machines to increase their efficiency. **System** category contains publications related to the system concept and cooperation of different material handling machines involving the selection and harmonization of the system elements. **Planning** category contains publications related to the planning, design, modelling, simulation and optimisation of different handling machines and systems. **Automation** category contains publications related to the automated handling solutions and their technical, informatics and control devices.

As Figure 2 shows, about 30-30% of the publications are related to the planning and operation of material handling, 20% to the handling systems and 10% to the automated solutions. Interesting result of the analysis is the low number of papers related to the structural researches (2%), where the cause is that the researches related to the elements are in generally the part of technology know-how and are not published.

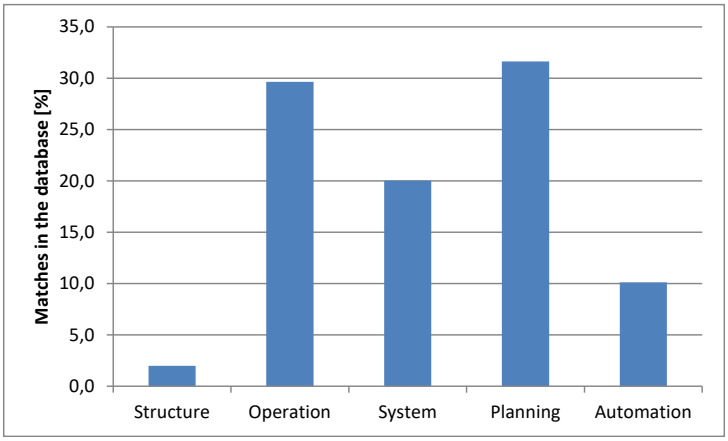

Figure 2. Distribution of the articles related to the research categories

Table I presents the distribution of the publications related to the handling machines among the research categories.

Table I.

Distribution of research categories at the main handling fields

Category	**Structure**	**Operation**	**System**	**Planning**	**Automation**	**Total**
Material handling	11	35	94	101	30	279
Forklift	2	20	6	6	2	43
AGV	4	54	90	99	101	212
Conveyor	7	113	75	115	10	450
Monorail	0	5	4	5	0	27
Crane	11	294	83	230	35	747
Total	**35**	**521**	**352**	**556**	**178**	**1758**

Based on Table I, we can say, that the planning is the leading research category for all equipment except forklifts. The researches related to operation are also important for forklifts, cranes, monorails and conveyors, and the focus for automation is the AGV.

As our paper targeted to analyse the planning process of material handling so we will deal only with the publications related to the planning category.

3. RESEARCHES RELATED TO THE PLANNING OF MATERIAL HANDLING

During the planning of material handling we are looking for suitable equipment and procedure to satisfy the supplying requirements of production processes. The planning process can be realized by system-based or task-based approaching.

The system-based approaching analyses the whole production and handling system and based on the system relations [3]. The most important element of the planning process is the comparison of different handling systems in objects, in devices, in handling tasks or in technology processes. Result of the planning is the adapting of a similar handling system (e. g. similar production firms of multinational companies).

The task-based approaching follows a given or iterative order of different planning subtasks (facility planning, element planning, functional planning, allocation planning, etc.) [4]. Planning process can be different based on the subtasks:

- single-task-planning, or augmented-planning,
- complex-planning (2-3 subtasks),
- integrated-planning (all subtasks).

There are many solution techniques and methods to solve single planning tasks [5], but their results are limited. During augmented-planning the focus is on a single task, but some parameters of other subtasks are also taken into consideration. Complex-planning combines 2-3 subtasks, which are linked by a certain aspect (e.g. technology), its complexity is depend on the involved subtasks [6]. The integrated planning concept theoretically realizes all planning subtasks, but because of the volume, complexity and iterative manner of the different tasks, in the practice, it can be solved only at simple planning cases [7].

According to the increasing of computational performance and to the development of optimisation methods, the integrated-planning can be applied more and more complex handling systems, but because of the complexity of the required methods and software applications, users can hardly understand the procedures so they cannot accept its using [8].

To avoid the black-box effect, new research concepts started during the last years, e. g. the process-based planning, which does not target to find the global optimum, but search a suitable and understandable solution using an easier logic [9].

To realise the planning processes and its steps, many planning devices, software and methods can be applied, so we link the publications in 7 categories based on [10]:

- General planning solutions,
- Modelling procedures,
- Advanced computer methods:
  - CAD software,
  - Knowledge-Based Systems,
  - Simulation processes,
  - Virtual Reality,
  - Optimisation methods.

The 556 matches, related to the planning of material handling in the Science Direct database, belongs to 472 papers, which can be linked to the 7 categories as presented in Figure 3. As Figure 3 shows, there are three main planning variations: the general planning (31%), the modelling (32%) and the advanced computer methods (37%), where the optimisation and simulation are the dominant.

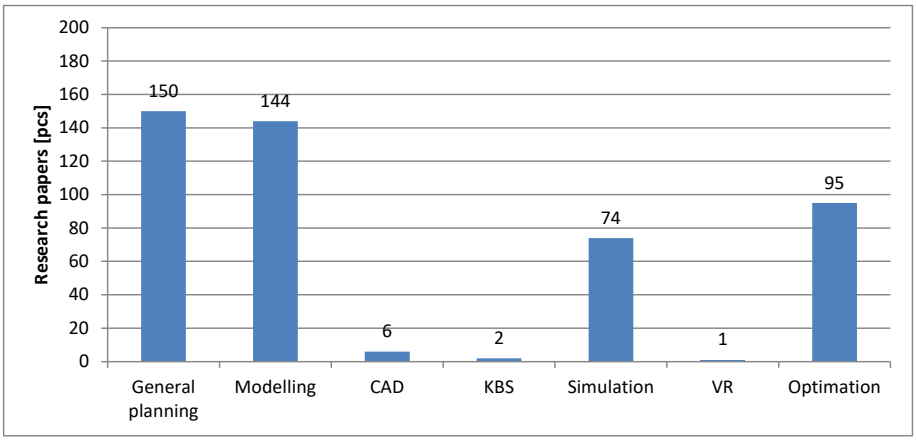

Figure 3. Distribution of the articles related to the planning methods

The number of the scientific publications is also changing in time, there was significant increasing in the last two decades (Figure 4). The average published paper number pro year was 5-6 before 2005, but this number increased to 30 in 2019. The most important cause of this tendency is the increasing publication activities of the scientists working in Asia and Africa.

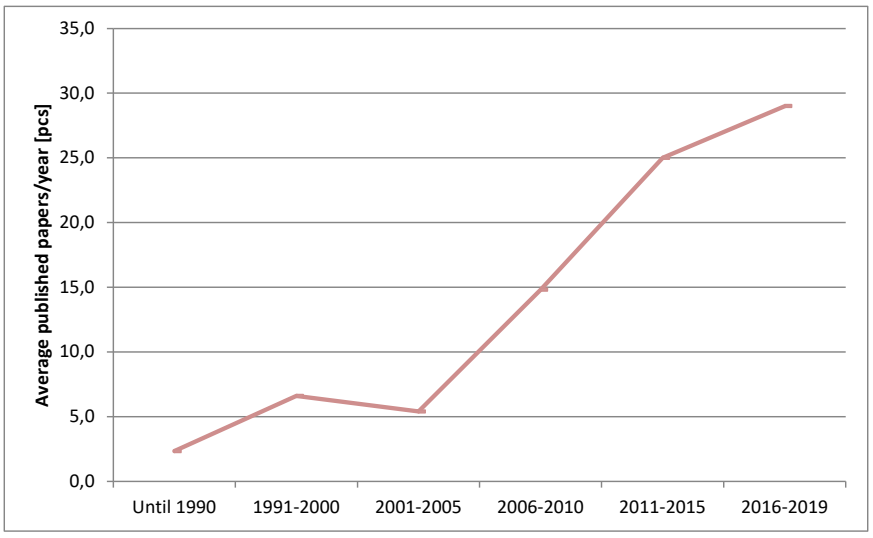

Figure 4. Quantity of the articles in the database till 2019

Analysing the time-distribution of the publications (Figure 5), we can see that the increasing in the advanced computer methods much higher (8-9 times) than in the classic planning methods (4 times). Based on the above-mentioned tendency, it is easy to predict that the number of the papers related to the advanced computer methods will be higher than the others at the end of the next ten years.

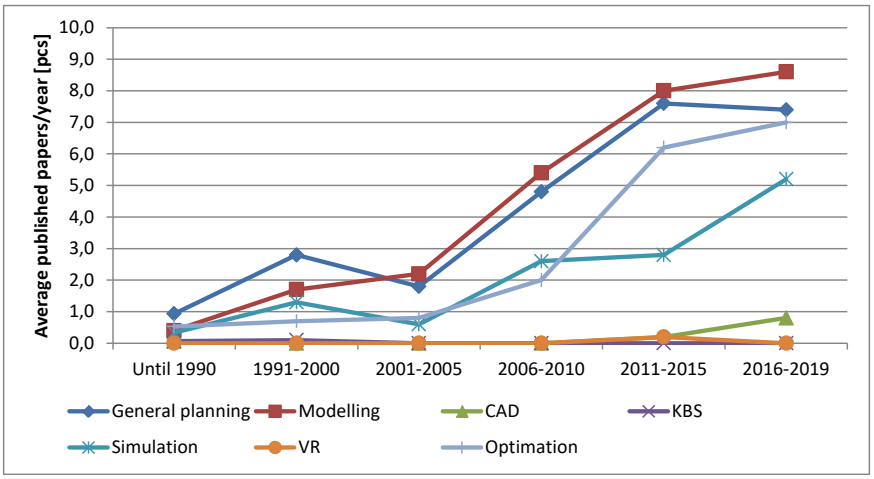

Figure 5. Quantity of the articles related to the planning methods

Another important conclusion of Figure 5 is the rare application of CAD, VR and KBS solutions in the material handling, but the scientific popularity of these methods also predicts a significant increasing in the next years.

Nowadays, the obsolescence of the research topics is much quicker than in the last century, so we will analyse only the publications after 2005. Another side we leave out the papers using CAD, VR and KBS solutions, because of their rare occurrence. Using the above-mentioned narrowing, we can count 317 scientific papers in the Science Direct database related to the planning of material handling between 2006 and 2019 (Figure 6).

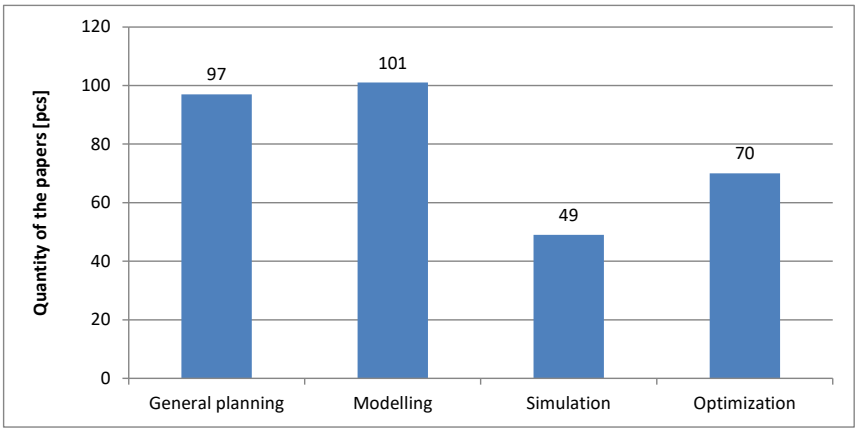

Figure 6. Quantity of the articles related to the planning methods between 2006 and 2019

4. MATERIAL HANDLING MACHINES IN THE PUBLICATIONS

Another important aspect of the research is the distribution of the papers among the different material handling machines. Near the half of the publications related to the planning of material handling deals with cranes (48%). Two other important machines in the papers are also the conveyors (22%) and AGVs (14%), 9% of the researches deal with complex handling systems using more than one machine types, only 6% of them related to other handling machines (Figure 7).

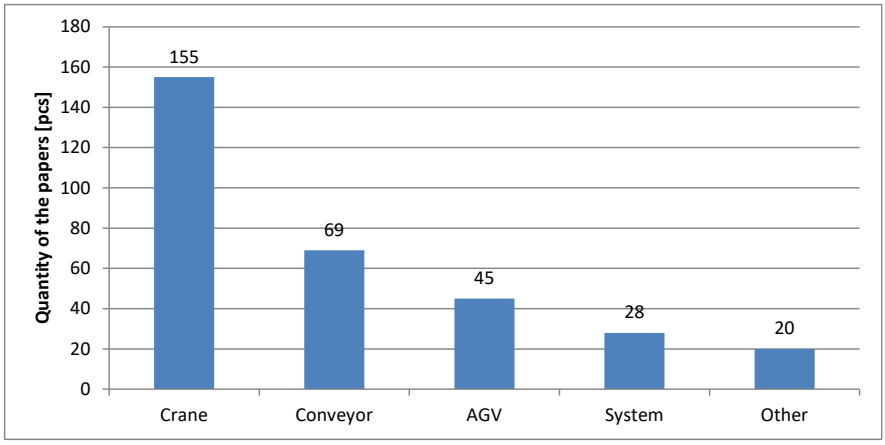

Figure 7. Distribution of the articles related to the handling solutions

It is worth to analyse the relations among the machines and the planning methods, which can be seen in Table II.

Table II.

Distribution of research methods related to the handling solutions

	Cranes	Conveyors	AGV	System	Other
General planning	41	21	20	11	4
Modelling	62	26	2	5	6
Simulation	14	12	10	8	5
Optimisation	38	10	13	4	5

Table II shows that roughly 2/3rd of the papers about cranes and conveyors use traditional planning methods, but at AGVs the half of the publications use advanced methods (simulation and optimisation). For complex handling systems the general planning (37%) and the simulation are the most often used (30%). The distribution of the other handling machines can be seen in Figure 8.

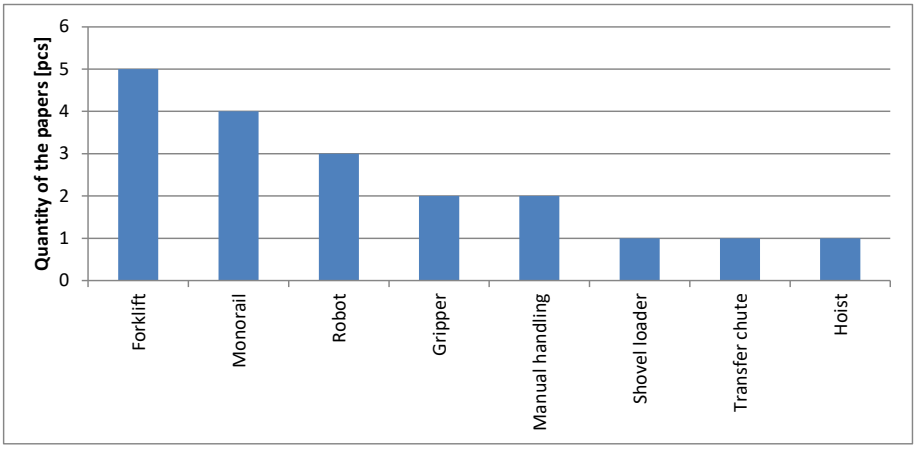

Figure 8. Distribution of the types of other handling machines

5. PLANNING PROCESS OF MATERIAL HANDLING IN THE DATABASE

The planning procedure of material handling is generally realised in exact planning steps which related to different planning subtasks. These subtasks can be linked to four different planning categories:

- system planning,
- structure planning,
- operation planning and
- layout planning.

The distribution of the publications among the planning categories can be seen in Figure 9.

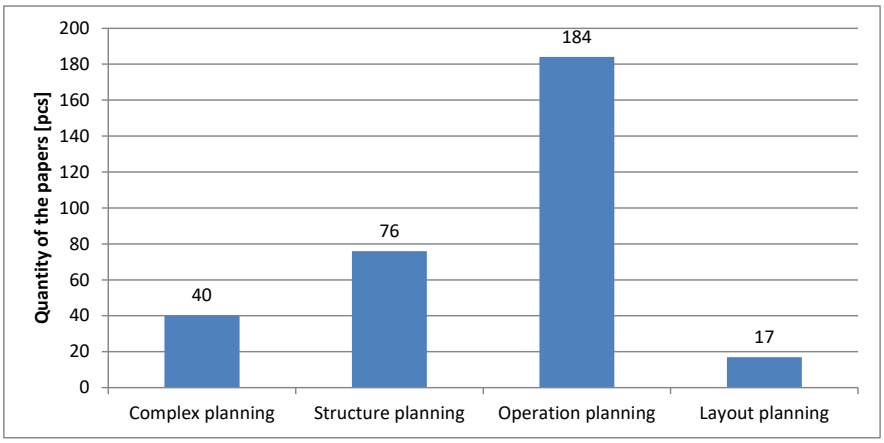

Figure 9. Distribution of the main planning categories

Figure 9 shows that the main planning category is the operation planning (58%), the structure planning has 24%, complex planning tasks has 13% and the least dominant is the layout planning (5%).

During **system planning**, the parameters of the handling processes are calculated, but the researches related to this topic generally are not linked to certain machines and technical solutions, so the analysed publications are not containing this aspect.

Papers related to **structure planning** deal with the elements and connections of individual handling machines, presents their most important and most problematic parts (Table III). The most frequent topics for discontinuous machines in the Science Direct database are the planning of the main structures (33%) and the dynamical behaviour of the machines (25%). More papers deal with also the driving and driver comfort (16%) and the gripping (8%).

80% of the papers related to the continuous machines deals with the planning and analysis of belt conveyors. Half of the publications related to the transport elements (belt, chain, etc.), 23% to the behaviour of the transported bulk solids and 10% to the support solutions of the different transport elements of the conveyors.

Table III.

Distribution of subtopics related to structure planning

	Crane	**Conveyor**	**AGV**	**System**	**Other**	**All**
Discontinuous						
Main structure	11				1	**12**
Dynamics	8				1	**9**
Driving/driver	3		1		1	**5**
Gripping	1				2	**3**
Other	2		2	1		**5**
Continuous						
Transport element		21				**21**
Material		9				**9**
Support		4				**4**
Other		7		1		**8**
Total	**25**	**41**	**3**	**2**	**5**	**76**

As the **operation planning** is the most important part of the research topics so we analysed their subtopics in more details (see Table IV.). Based on the table, we can see that in the aspect of technical solutions the control (20%) and the motion (9%) of cranes, in the aspect of operation parameters the scheduling (12%) and the allocation (7%) of cranes lead among the planning topics. Another important fact, that the control of the machines (general control and the control of the elements) is the most frequent research topic (30%) among the operation planning.

During our research, we analysed only those papers, which deal with the **layout planning** of the handling machines. As in the literature, the layout planning methods do not take in generally the parameters of the handling devices into account so we did not find so much suitable papers in this topic. Among the analysed publications the crane erection is the dominant (65%), but the optimal AGV line planning is also significant (25%).

The **complex planning** category means those papers which integrate the solution

process of two or more subtasks from different planning categories. Nowadays, there are more and more requirement from the industrial side to make complex planning processes (system planning, system analyses, etc.) to take control on every parts of the production systems.

Table IV.

Distribution of subtopics related to operation planning

	Crane	Conveyor	AGV	System	Other	All
General control	36	6	8	4	1	**55**
Scheduling	23	0	5	1	1	**30**
Motion	15	5	2	11	0	**33**
Performance	3	5	5	0	4	**17**
Allocation	12	0	2	0	0	**14**
Safety	6	3	1	0	2	**12**
Other	8	3	9	1	2	**23**
Total	**103**	**22**	**32**	**17**	**10**	**184**

6. ROLE OF THE PLANNING PROCESSES IN THE DATABASE

During the research we cannot find paper in the Science Direct database, which presents general, integrated planning process for material handling. To analyse the planning processes in the publications we created certain categories in the aspect of planning complexity. Table V presents the distribution of the planning processes taking the complexity into consideration. To measure the complexity, we used the number of machine types and subtasks as reference data.

Table V.

Distribution of research papers in the aspect of planning complexity

	One subtask		Complex planning		Total
	One machine type	General solution	One machine type	General solution	
Crane	102	42	10	1	**155**
Conveyor	59	5	5	0	**69**
AGV	0	36	0	9	**45**
System planning	9	11	5	3	**28**
Other	14	4	2	0	**20**
Total	**184**	**98**	**22**	**14**	**317**

Based on the data in Table V, we can see that 89% of the 317 papers related to the planning of material handling focus to one single handling subtask and roughly 2/3rd of them limited to one given machine type. The remained 11% deal with complex planning involving more than one subtasks or machine types.

6.1. Cranes

There are 155 publications in the Science Direct database, which deal with crane planning, but only 11 papers (8%) present complex planning process. Three of the papers are only augmented planning [15, 16, 17], which focus on a single task, but some parameters of other subtasks are also taken into consideration.

Real complex planning processes are presented at Taubmann et al. [18] and Han et al. [19], where two planning subtasks (structure and operation planning) are integrated. Safarzadeh et al. [20] deals also with these two subtasks, but involves some elements form the whole planning process. Wu et al. [21] presents a simple structural calculation fitted into a standard planning method.

The first paper which uses integrated planning is the publication of Marzouk and Abubakr [22] about tower cranes, where the authors focus on the selection and layout planning. Ji and Leite [23] have similar topics in their publication on automated tower crane planning.

Han et al. [24] integrate the simulation into the selection process of mobile cranes, Taghaddos et al. [25] deal also the selection and application of mobile cranes regarding to the needs of the construction industry.

Summarising the above-mentioned publications, we can see that papers related to the complex planning of cranes focus on mainly the selection process and involve some additional planning subtask (only one in most of the cases). Other interesting fact, that most of these publications related to the construction building area.

6.2. Conveyors

There are 69 publications in the Science Direct database, which related to the planning of different conveyors, but only 5 of them present complex planning process.

Three of the publications deal with belt conveyors, Alamia et al. [26] integrate the handling device into the planning of a dryer machine and use a simulation analysis. Schmidt and Leiking [27] also apply simulation for planning of a band cover conveyor, Masaki et al. [28] deal with the dimensioning of multi-drive belt conveyors in the aspect of the operation costs.

Special planning processes for pneumatic conveyors are described in Lee and Lee [29] and Zeggari et al. [30], the first paper focuses on the operation parameters, the other one deal with the structural building.

As a conclusion, we can say that the publications related to the conveyors include special machines or tasks, where the integrated planning requires much simpler process with small number of steps or simple elements.

6.3. AGV

There are 45 publications in the Science Direct database, which related to the planning of AGV. All of them give general solution without any structural limitation. 9 of the publications apply complex approach, but 3 of them focus mainly to the control and the operation planning aspects [31, 32, 33].

Real complex approach is applied at Le-Anh & De Koster [34], where the operation planning is combined with the determination of the required vehicle quantity. Um at al. [35]

integrates the operation planning of AGV's into the planning of flexible manufacturing systems. Li et al. [36] combines the facility planning and the control planning of AGV's. Two papers use simulation analysis for AGV, Vavrik et al. [37] combines the determination of the required vehicle quantity with the operation planning, Yan et al. [38] combines the maintenance process with the operation planning.

In the aspect of the complex planning process, Vis [39] gives the widest picture, he presents a general overview about all part of the planning of AGV, and presents detailed analysis of the related international literature from the year 2006.

6.4. System planning

Minor part of the publications (9%) is not device specific, they use system concept during the planning process. There are 28 publications in the Science Direct database, which deal with the planning of handling systems without device pre-definition, however most of them (20) focus to one planning subtask.

8 papers apply complex planning approach, the earliest is Ioannau [40], which presents the most comprehensive planning process for complex handling tasks. Sujono & Lashkari [41] looks for the best handling devices for flexible manufacturing systems based on cost minimalization. Meng et al. [42] presents complex planning for material handling of coal mines using simulation analysis. Ritter et al. [43] deals with the handling of excavated materials of road tunnel building. Mital et al. [44] presents risk-based planning of material handling and storage handling systems. Wang et al. [45] builds handling systems and simulates their operation. Yamazaki et al. [46] deals with the lean aspects of the handling devices of automation lines. Chen et al. [47] presents the capacity planning and optimization of automated material handling systems.

As a result of our review, we can say that the integrated planning concept is much more often used for system planning than in other planning tasks.

6.5. Other devices

In the Science Direct database, we found 20 papers which related to other material handling machines than which are described in the above-mentioned categories. Most of them (18) deal with one exact planning subtask, only 2 use complex approach.

Han et al. [48] presents planning process for handling robots, but focuses mainly to the structural aspects. Netland et al. [49] deals with monorail design, presents mainly the positioning and control solutions.

7. CONCLUSIONS

After the detailed analysis of the publications related to the planning of material handling, we can find no paper in the Science Direct database which deals with general integrated planning of material handling.

89% of the 317 papers related to the planning of material handling deal with different aspects of one subtask, and 60% of them focus on one given handling device. Complex planning of given machines can be found only in 36 papers.

In case of cranes, the papers related to complex planning focus on the machine selection, the other planning topics are on the side of the interest. Papers related to the conveyor planning deal mainly with one special task - for instance the effects from the load

mass - or special machine solutions, where the process does not require the integrated scheme. Only one publication related to AGV's uses near integrated planning [39], the others have more simple process, where only 2 or 3 subtasks are integrated, or one task is dominant.

The integrated planning approach appears mainly at handling system planning (8 papers), where the integration involves more planning subtasks and the related manufacturing process elements.

Summarising the research, we can say that most of the publications related to the planning of material handling focus on one subtask. The other papers, which deal with complex planning focus on one task but takes some aspect of the others into account. Real integration of one or two planning subtasks is also rear (1-2%).

Based on the above-mentioned consequences, we can say that the integrated planning is an important research area, which can give place for new planning concepts, for example the process-based planning [9].

ACKNOWLEDGEMENTS

The described article/presentation/study was carried out as part of the EFOP-3.6.1-16-2016-00011 "Younger and Renewing University – Innovative Knowledge City – institutional development of the University of Miskolc aiming at intelligent specialisation" project implemented in the framework of the Szechenyi 2020 program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

REFERENCES

[1] Telek, P. (2018). Anyagmozgató rendszerek korszerű tervezési módszerei. *Gépgyártás 57*(1-2), 70-77.

[2] Telek, P., Illés, B., Landschützer, C., Schenk, F. & Massi F. (2018). Material handling machines and systems - UMi-TWINN project contribution. *Advanced Logistic Systems - Theory and Practice 12*(1), 7-20. https://doi.org/10.32971/als.2019.001

[3] Bányai, T. (2012). Integrált anyagáramlási rendszerek strukturált modellezése. *GÉP 63*(4), 83-86.

[4] Cselényi, J., Illés, B. (ed.) (2006). *Anyagáramlási rendszerek tervezése és irányítása I.* Miskolci Egyetemi Kiadó, Miskolc

[5] Jiang, S., Nee, A. Y. C. (2013). A novel facility layout planning and optimization methodology. *CIRP Annals - Manufacturing Techn. 62*, 483-86. https://doi.org/10.1016/j.cirp.2013.03.133

[6] Ortner-Pichler, A., Landschützer, C. (2017). Improving geometry manipulation capabilities of Knowledge-based Engineering applications by the versatile integration of 3D-CAD systems. In *CD proc. of MultiScience - XXXI. microCAD Int. Multidiscipl. Sci. Conf.* (C1: 3.), University of Miskolc https://doi.org/10.26649/musci.2017.044

[7] Telek, P. (2013). Equipment preselection for integrated design of materials handling systems. *Advanced Logistic Systems - Theory and Practice 7*(2), 57-66.

[8] Welgama, P. S., Gibson, P. R. (1995). A Hybrid Knowledge Based/Optimisation System for automated Selection of Materials Handling System. *Computers Ind. Engng. 28*(2), 205-217. https://doi.org/10.1016/0360-8352(94)00200-7

[9] Telek, P. (2018). Process-based planning of material handling in manufacturing systems. *IOP Conference Series: Materials Science And Engineering 448*, 012018. https://doi.org/10.1088/1757-899X/448/1/012018

[10] Telek, P., Trummer, W. (2018). Introduction of Demo3D into the scientific education of material handling. *Advanced Logistic Systems - Theory and Practice 12*(1), 61-76. https://doi.org/10.32971/als.2019.005
[11] Milton, N. (2008). *Knowledge Technologies*. Monza: Polimetrica S.a.s.
[12] Parisi, T. (2016). *Learning Virtual Reality*. O'Reilly Media, 1005 Gravenstein Highway North, Sebastopol, CA, USA
[13] McGregor, I. (2015). The Emulate3D framework for the emulation, simulation, and demonstration of industrial systems. *In Proceedings of the 2015 Winter Simulation Conference*, Huntington Beach, 4101 - 4115. IEEE, CA, USA
[14] Bányai, A., Bányai, T. & Illés, B. (2017). Optimization of Consignment-Store-Based Supply Chain with Black Hole Algorithm. *COMPLEXITY 2017*, 6038973. https://doi.org/10.1155/2017/6038973
[15] Briskorn, D. & Dienstknecht, M. (2019). Mixed-integer programming models for tower crane selection and positioning with respect to mutual interference, *European Journal of Operational Research*, *273*(1), 160-174, https://doi.org/10.1016/j.ejor.2018.07.033.
[16] Arena, A., Casalotti, A., Lacarbonara, W. & Cartmell, M. P. (2015). Dynamics of container cranes: three-dimensional modeling, full-scale experiments, and identification, *International Journal of Mechanical Sciences*, *93*, 8-21, https://doi.org/10.1016/j.ijmecsci.2014.11.024.
[17] Al-Hussein, M., Athar Niaz, M., Yu, H. & Kim, H. (2006). Integrating 3D visualization and simulation for tower crane operations on construction sites, *Automation in Construction*, *15*(5), 554-562, https://doi.org/10.1016/j.autcon.2005.07.007.
[18] Taubmann, G., Brochet, L., Liniers, M., Medrano, M., Sarasola, X., Botija, J., Alonso, J. & Damiani, C. (2009). Design of an overhead crane for the ITER NB cell remote handling maintenance operations, *Fusion Engineering and Design*, *84*(7–11), 1827-1832, https://doi.org/10.1016/j.fusengdes.2008.11.058.
[19] Han, D-S., Yoo, S-W., Yoon, H-S., Kim, M-H., Kim, S-H. & Lee, J-M. (2011). Coupling analysis of finite element and finite volume method for the design and construction of FPSO crane, *Automation in Construction, 20*(4), 368-379, https://doi.org/10.1016/j.autcon.2010.11.007.
[20] Safarzadeh, D., Sulaiman, S., Aziz, F. A., Ahmad, D. B. & Majzoobi, G. H. (2011). The design process of a self-propelled floor crane, *Journal of Terramechanics, 48*(2), 157-168, https://doi.org/10.1016/j.jterra.2010.12.002.
[21] Wu, X., Chen, B., Zhang, D. & Li, J. (2011). The Research on Optimal Design of Large Metallurgical Crane, *Procedia Engineering, 24*, 783-787, https://doi.org/10.1016/j.proeng.2011.11.2737.
[22] Marzouk, M. & Abubakr, A. (2016). Decision support for tower crane selection with building information models and genetic algorithms, *Automation in Construction, 61*, 1-15, https://doi.org/10.1016/j.autcon.2015.09.008.
[23] Ji, Y. & Leite, F. (2018). Automated tower crane planning: leveraging 4-dimensional BIM and rule-based checking, *Automation in Construction, 93*, 78-90, https://doi.org/10.1016/j.autcon.2018.05.003.
[24] Han, S. H., Hasan, S., Bouferguene, A., Al-Hussein, M. & Kosa, J. (2018). An integrated decision support model for selecting the most feasible crane at heavy construction sites, *Automation in Construction, 87*, 188-200, https://doi.org/10.1016/j.autcon.2017.12.009.
[25] Taghaddos, H., Hermann, U. & Abbasi, A. B. (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.
[26] Alamia, A., Ström, H. & Thunman, H. (2015). Design of an integrated dryer and conveyor belt for woody biofuels, *Biomass and Bioenergy*, *77*, 92-109, https://doi.org/10.1016/j.biombioe.2015.03.022.

[27] Schmidt, T. & Leiking, L. (2009). A novel simulation model for the dimensioning of cover band conveyors, *Mechanism and Machine Theory*, *44*(9), 1795-1805, https://doi.org/10.1016/j.mechmachtheory.2009.03.004.
[28] 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.
[29] Lee, H. G. & Lee, D. G. (2006). Design of a large LCD panel handling air conveyor with minimum air consumption, *Mechanism and Machine Theory*, *41*(7) 790-806, https://doi.org/10.1016/j.mechmachtheory.2005.10.009.
[30] Zeggari, R., Yahiaoui, R., Malapert, J. & Manceau, J. F. (2010). Design and fabrication of a new two-dimensional pneumatic micro-conveyor, *Sensors and Actuators A: Physical*, *164*(1–2), 125-130, https://doi.org/10.1016/j.sna.2010.09.013.
[31] Kim, K. S. & Chung, B. D. (2007). Design for a tandem AGV system with two-load AGVs, *Computers & Industrial Engineering*, *53*(2) 247-251, https://doi.org/10.1016/j.cie.2007.06.016.
[32] Hsueh, C-F. (2010). A simulation study of a bi-directional load-exchangeable automated guided vehicle system, *Computers & Industrial Engineering*, *58*(4) 594-601, https://doi.org/10.1016/j.cie.2009.12.008.
[33] Cheong, H-W. & Lee, H. (2018). Concept Design of AGV (Automated Guided Vehicle) Based on Image Detection and Positioning, *Procedia Computer Science*, *139*, 104-107, https://doi.org/10.1016/j.procs.2018.10.224.
[34] Le-Anh, T. & De Koster, M. B. M. (2006). A review of design and control of automated guided vehicle systems, *European Journal of Operational Research*, *171*(1), 1-23, https://doi.org/10.1016/j.ejor.2005.01.036.
[35] Um, I., Cheon, H. & Lee, H. (2009). The simulation design and analysis of a Flexible Manufacturing System with Automated Guided Vehicle System, *Journal of Manufacturing Systems*, *28*(4) 115-122, https://doi.org/10.1016/j.jmsy.2010.06.001.
[36] Li, Q., Adriaansen, A. C., Udding, J. T. & Pogromsky, A. Y. (2011). Design and Control of Automated Guided Vehicle Systems: A Case Study, *IFAC Proceedings Volumes*, *44*(1), 13852-13857, https://doi.org/10.3182/20110828-6-IT-1002.01232
[37] Vavrík, V., Gregor, M. & Grznár, P. (2017). Computer Simulation as a Tool for the Optimization of Logistics Using Automated Guided Vehicles, *Procedia Engineering*, *192*, 923-928, https://doi.org/10.1016/j.proeng.2017.06.159.
[38] Yan, R., Dunnett, S. J. & Jackson, L. M. (2018). Novel methodology for optimising the design, operation and maintenance of a multi-AGV system, *Reliability Engineering & System Safety*, *178*, 130-139, https://doi.org/10.1016/j.ress.2018.06.003.
[39] Vis, I. F. A. (2006). Survey of research in the design and control of automated guided vehicle systems, *European Journal of Operational Research*, *170*(3), 677-709, https://doi.org/10.1016/j.ejor.2004.09.020.
[40] Ioannou, G. (2007). An integrated model and a decomposition-based approach for concurrent layout and material handling system design, *Computers & Industrial Engineering*, *52*(4), 459-485, https://doi.org/10.1016/j.cie.2007.02.003
[41] Sujono, S. & Lashkari, R. S. (2007). A multi-objective model of operation allocation and material handling system selection in FMS design, *International Journal of Production Economics*, *105*(1), 116-133, https://doi.org/10.1016/j.ijpe.2005.07.007
[42] Meng, C., Nageshwaraniyer, S. S., Maghsoudi, A., Son, Y-J. & Dessureault, S. (2013). Data-driven modeling and simulation framework for material handling systems in coal mines, *Computers & Industrial Engineering*, *64*(3), 766-779, https://doi.org/10.1016/j.cie.2012.12.017
[43] Ritter, S., Einstein, H. H. & Galler, R. (2013). Planning the handling of tunnel excavation material – A process of decision making under uncertainty, *Tunnelling and Underground Space Technology*, *33*, 193-201, https://doi.org/10.1016/j.tust.2012.08.009

[44] Mital, P., Goetschalckx, M. & Huang, E. (2015). Robust material handling system design with standard deviation, variance and downside risk as risk measures, International *Journal of Production Economics*, *170*, Part C, 815-824, https://doi.org/10.1016/j.ijpe.2015.02.003

[45] Wang, C-N., Lee, Y-H., Hsu, H-P. & Nguyen, D-H. (2016). The heuristic preemptive dispatching method for convey-based automated material handling system of 450mm wafer fabrication, *Computers & Industrial Engineering*, *96*, 52-60, https://doi.org/10.1016/j.cie.2016.03.017

[46] Yamazaki, Y., Shigematsu, K., Kato, S., Kojima, F., Onari, H. & Takata, S. (2017). Design method of material handling systems for lean automation - Integrating equipment for reducing wasted waiting time, *CIRP Annals*, *66*(1), 449-452, https://doi.org/10.1016/j.cirp.2017.04.011

[47] Chen, W., Wang, Z. & Chan, F. T. S. (2017). Robust production capacity planning under uncertain wafer lots transfer probabilities for semiconductor automated material handling systems, *European Journal of Operational Research*, *261*(3) 929-940, https://doi.org/10.1016/j.ejor.2017.02.026

[48] Han, L., Ruijuan, C. & Enrong, M. (2016). Design and Simulation of a Handling Robot for Bagged Agricultural Materials, *IFAC-PapersOnLine*, *49*(16) 171-176, https://doi.org/10.1016/j.ifacol.2016.10.032

[49] Netland, Ø., Granheim Farstad, J. M. & Welo, T. (2017). Design of a Modular Extrusion-based Aluminum Monorail System for Highly Accurate Car Positioning, *Procedia CIRP*, *60*, 8-13, https://doi.org/10.1016/j.procir.2017.02.031.