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MATERIAL HANDLING EQUIPMENT SELECTION ALGORITHM FOR PRODUCTION WORKPLACES

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Abstract: *Nowadays, the consumption is the most significant factor in the economy. The consumption requires different items, which must be produced by the industry. Production processes are realized mainly on workplaces, so their importance is inevitably. This paper presents an overview about the planning process of material handling machines, especially for the production workplaces. The research, shown in this paper, targets to select the most suitable material handling equipment for different production workplaces. The topic presented in this paper deals with the building of selection algorithm for the exclusion of non-applicable equipment types. To show the useability of the concept an example will also be presented.*

Key words: *Workplace handling, selection algorithm, material handling equipment selection.*

1. INTRODUCTION

Nowadays, the consumption is the most significant factor in the economy. The consumption stands in the focus of the everyday life of the people and determines the economic activities of the societies. The consumption requires different items, which must be produced by the industry. Production processes are realized mainly on workplaces, so their importance is inevitably. To increase the efficiency of the production processes advanced manufacturing technologies and handling solutions are required.

This paper presents an overview about the planning process of material handling machines, especially for the production workplaces. There are many material handling machine types, so the equipment selection process is a crucial part of the planning procedure.

The research, shown in this paper, targets to develop a model, which can help to select the most suitable material handling equipment for different production workplaces. The topic presented in this paper deals with the building of selection algorithm for the exclusion of non-applicable equipment types. To show the applicability of the concept an example will also be presented.

2. MATERIAL HANDLING ON WORKPLACES

Production workplace means an object, where a given production operation can be realized. There are many types of workplaces, which can be different in physical, production, handling, or other aspects [1].

Material handling means a simple task to move units from a source object to a destination point. Naturally, the characterizations of the given task can be very different, and the realization process can also be very complicated. If we link some material handling

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tasks suited to certain logic and take them together into account, we get a material handling process as a result [2]. The realization of a given task involved in a handling process always influences all other tasks in the process.

The workplace handling is the smallest part of the material handling system of a manufacturing process [3]. It involves only the handling of the input materials and elements, the internal handling of the elements and the processed units, and the handling of the output products of a given workplace [4]. Realization of the workplace handling depends on the physical environment, which contains different functional areas: production, operator, storage, loading, transport, inspection, etc. areas [5], but in our research we use the model defined in paper [6] which takes only 4 different areas into account (Fig. 1).

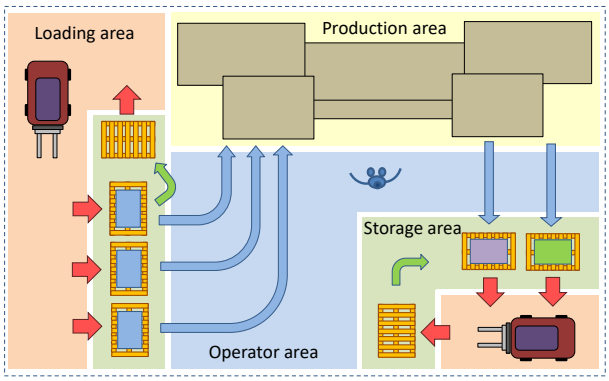

Fig 1. Workplace handling areas [6]

The number, size and location of the individual areas can be different depending on the characterisation of the given workplace. In the aspect of the handling process, different workplace variations (head-type, through-flow, complex handling, etc.) can be described based on the external and the internal handling processes [6].

For the analysis of the handling processes of the workplaces a material handling model must be used. If we add vertical sizes to the workplace areas, a prismatic volume is formed [6], which involves the related handling activities as individual points (Fig. 2).

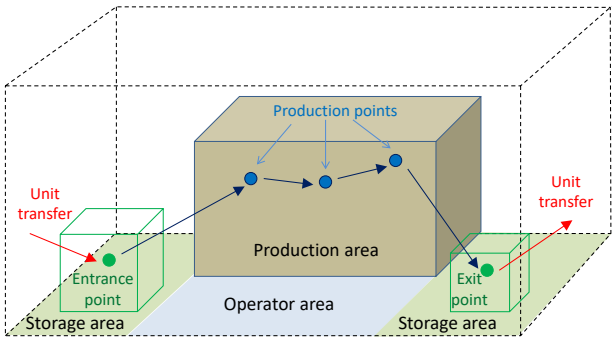

Fig. 2. Simple handling model of workplaces [6]

As Fig. 2 shows, the internal handling process is a chain of different handling operations (blue arrows), which starts at the entrance point, involves different production points (operation, picking and storing points) and is stopped at the exit point. The different steps can be realized individually or combined with others. Based on the workplace and unit parameters, the general model can be simplified or more complex depending on the given tasks (one-point, two-point, three-point model, etc., see [4]).

The workplace handling can be separated into two parts in the aspect of the equipment: internal and external handling. The task of the external handling machine is to transport goods into the entrance point and take goods off from the exit point. The internal handling machine takes the goods at the entrance point, moves them among the production points and leaves them on the exit point (Fig. 2). There are three different cases of the workplace handling process based on the applied machine types [7]:

1. Separate machines for the internal and external handling.
2. External handling machine also realize the internal tasks (e. g. forklift).
3. Internal handling machine handles the goods on the entrance and exit points, the external machine is only a transporter without loading capability (e. g. pallet car).

3. MATERIAL HANDLING EQUIPMENT SELECTION

Main objective of the equipment selection is to find the best material handling solution for all related handling tasks. During the selection process the optimal solution is searched along a given objective function with the comparison of the parameters of the material handling devices and the handling relations.

Materials handling relation means a special connection between two objects, which contains any kind of handling activity. Handling relations can be defined by the two linked objects and one handling parameter existing among them [8]. The most important parameters used in handling relations are the types and quantities of the goods, the distances and routes among the objects, the handling costs, the handling time requirements, the handling circumstances and conditions, the disturbing objects and problems, etc. [9].

At the other side the handling machines also have different parameters (e. g. capacities, velocities, loading and transport capabilities) which must be taken into consideration during the selection process (see [10]).

The equipment selection procedure can be segmented into different steps depends on the compared parameter types, which can be exclusion-type, limitation-type, or numerical parameters [10].

Exclusion-type parameters can exclude the application of certain equipment types (for example: roller conveyor cannot be used for bulk solids). They can be unambiguous exclusions (function, goods type, etc.) and definable exclusions (operation characteristic, handling method, track-line, etc.).

Limitation-type parameters do not exclude equipment types, but they can narrow their practical application field (e. g. forklifts cannot be used for individual handling of small boxes). They can be numerical limitations (unit parameters, task parameters, etc.) and not numerical limitations (object parameters, track types, etc.).

Numerical parameters are the bases of the analytic design process, their values can be different at different materials handling machines (route length, energy consumption, etc.). These parameters can also be used in different formulas for the comparison of machine types (see [11]).

Based on the different parameter types, the equipment selection procedure has three phases: 1. Exclusion of the non-suitable solutions, 2. Taking the limitations into account, 3. Comparison of the applicable machine types.

4. EQUIPMENT SELECTION FOR WORKPLACE HANDLING

As the activities and environment of workplaces are determined, the machine types which can be used for the handling are limited. In this paper we take only the single workplace handling solutions into consideration, which can be efficiently applied for one workplace, without any limitations [4]. Table I gives an overview about the most often used machines for workplaces and their most important parameters.

Table I.

Handling parameters of material handling equipment used in workplaces [4]

Equipment types	Operation point limits	Horizontal moving	Vertical moving	Reaching direction
1. Running hoists	vertical area along a line	along a line	no limits	upside
2. Jib cranes	space above a given area	rotation and radial direction	no limits	upside
3. Linear manipulators	depend on type	depend on type	depend on type	depend on type
4. Articulated robots	depend on type	rotation and linear directions	rotation and linear directions	multi
5. Conveyors	along a line	along a line	limited	front, upside

The equipment selection procedure defined in the previous chapter has the next phases for production workplaces [7]:

1. Exclusion of the solutions which are not suitable for workplace handling of the given goods.
2. Taking the physical parameters and manufacturing environments of the workplace as limitations into account.
3. Comparison of the applicable handling solutions.

4.1. Exclusion of the non-suitable machine types

Main objective of this selection phase is to exclude those handling machines, which cannot be applied for the given workplaces based on the exclusion-type parameters.

Exclusion parameters of handling machines can be grouped into four categories (Table II.), which characteristically separate the different devices (based on [10]):

- material handling functions,
- track line solutions,
- serving characteristics,
- goods handling specifications.

Examination of the machine parameters in the aspects of the workplace specifications results the exclusion of the non-applicable machine types.

Table II.

Exclusion parameters of handling machines of workplaces

Equipment types	Function	Track line	Serving method	Goods handling
1. Running hoists	loading	high track	along tracks + vertical	hanging
2. Jib cranes	loading	high track	rotation + vertical	hanging
3. Linear manipulators	loading	ground track	along tracks	clutching
4. Articulated robots	loading	rotating track	complex area	clutching
5. Conveyors	transport, storage	ground track, high track	additional device	hanging, surface

4.2. Taking the physical parameters and manufacturing environments as limitations into account

After the exclusion phase, the remained machine types are further examined. Main task of the second selection phase is the examination of the applicability of the suitable handling machines in the given workplace environment. Limitation-type parameters define limit values for different numerical parameters.

Taking not numerical limitation-type parameters into account is not easy and in generally requires practical experience [10] (for example: clutching of a unit with complex shape can be easily solved by hanging, but it excludes the application of some handling device). Main limitation-type parameters for workplace handling are:

- numerical:
  - unit parameters (size, geometry, mass, etc.),
  - time limits of the handling tasks,
  - order rule of the tasks,
  - slope within the transport lines, etc.
- not numerical:
  - handling regulations,
  - shapes of the goods,
  - receiving conditions of the goods,
  - track-line limitations (closed areas),
  - height limits,
  - turnover limits, etc.

The application of the limit values for the individual machines can also exclude some of the equipment types (e. g. safe mounting of crane structure, see [4]).

4.3. Comparison of the applicable machine types

After the first two phases, all remained machine types will be suitable as a handling solution for the given production workplace.

The comparison procedure is based on one or more numerical parameters in every case, the most important ones are [7] the transport distances (vertical, horizontal, etc.), the

operation times (transport, loading, waiting, etc.), the predefined limits (e. g. production start time), the machine parameters (capacities, utilizations, etc.), etc.

Some of the above-mentioned parameters cannot be previously defined (e. g. waiting times), so such comparison methods are required which can take the complex and stochastic effects into consideration (e. g. a simulation analysis with Technomatix Plant Simulation [12] software, see [7].

Table III shows the numerical parameters of the handling tasks and the applicable machines, the values and the relations of them can be the base for the comparison process.

Table III.

Numerical parameters of unit handling [10]

Material flow parameters	**Device parameters**
transport distance	→ transport velocity
service time	
stiffness of the line	→ transport angle
heights of loading positions	→ loading height
size of the units	→ handling sizes
mass of the units	→ carrying capacity
serving intensity	→ number of the devices

5. SELECTION ALGORITHM FOR THE EXCLUSION OF WORKPLACE HANDLING MACHINES

After the presentation of the phases of the selection procedure, it is possible to define a selection algorithm for production workplaces.

The objective of our research is to describe a general selection algorithm; however, it is not an easy task, because of the large differences among the workplace structures and handling solutions.

To reach our target, we follow a step-by-step concept, in which we will define special algorithms for the individual phases used for different example workplaces and after it, in the knowledge of the specific methods we can build a general algorithm.

As the first step of this concept, in this paper we describe an algorithm to realize the exclusion phase of the equipment selection process (Fig. 3).

The equipment selection algorithm (Fig. 3) for the exclusion of machine types is based on the parameters included into Table II. The algorithm analyses all applicable handling machine types and results smaller variation. The output of the algorithm will be the input of the next selection phase (limitations).

To present the operation of the algorithm we apply it for the laboratory workplace of the Institute of Production Technology of the Slovak University of Technology, in Trnva [13]. The structure of the example workplace can be seen on Fig. 4.

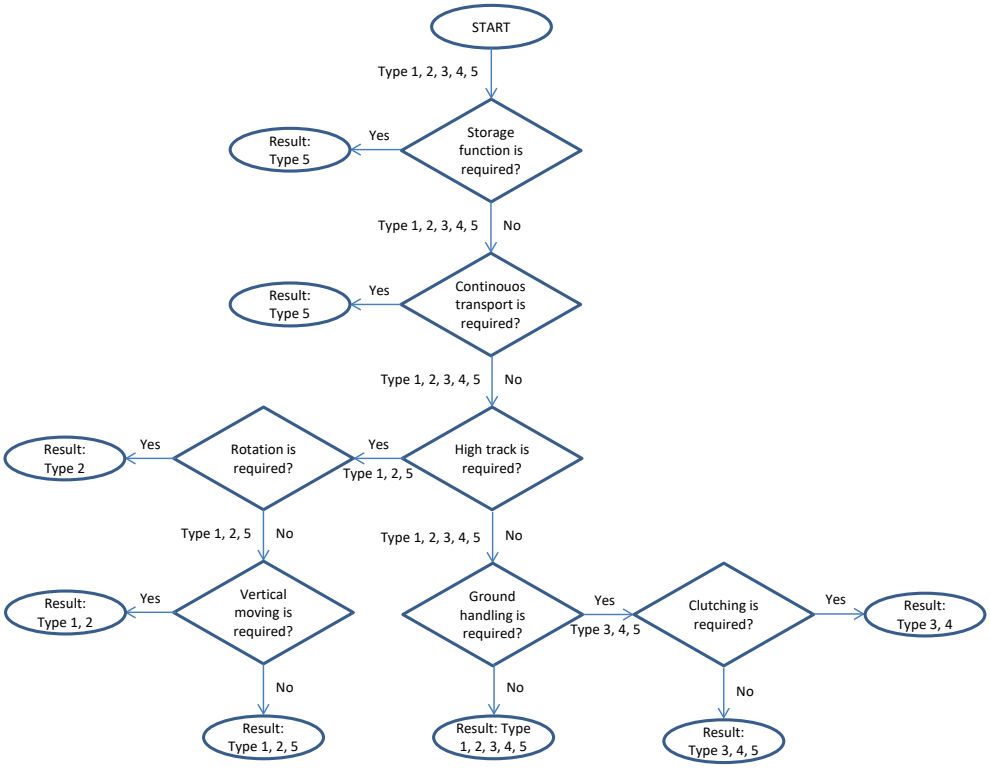

Fig. 3. Equipment selection algorithm for the exclusion of machine types

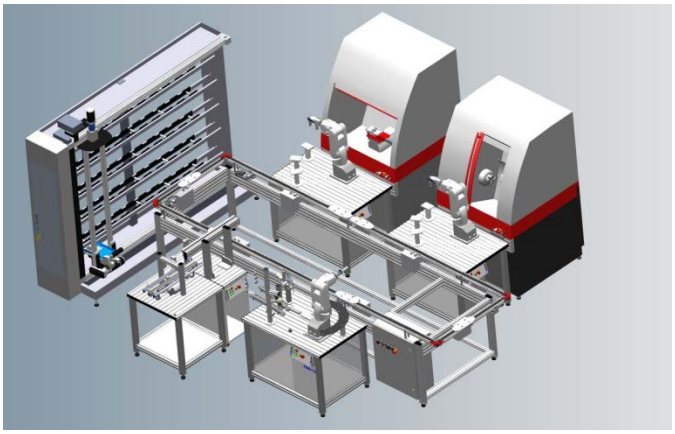

Fig. 4. Workplace structure of the Institute of Production Technology [13]

To define the details of the example workplace we applied the model described in [11] and defined 5 handling points presented in Fig. 5. In the aspect of the production procedure, in the example we transport one element type among 5 handling points, their physical and functional data are involved into Table IV.

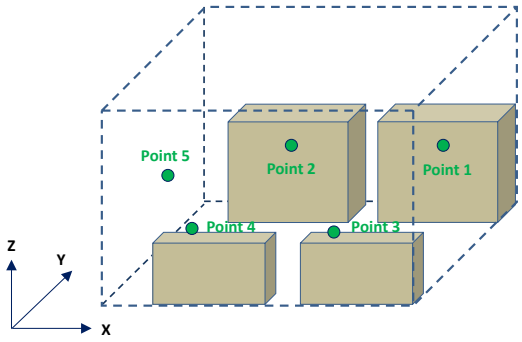

Fig. 5. Structure and handling points of the example workplace

Table IV.

Data of the predefined handling points of the example workplace

Handling points	Coordinates			Function	Location
	X	Y	Z		
Point 1	3	4	1,5	Production	Front side
Point 2	2	4	1,5	Production	Front side
Point 3	3	1	1	Production	Upside
Point 4	1	1	1	Production	Upside
Point 5	0	2,5	1	Production	Left side

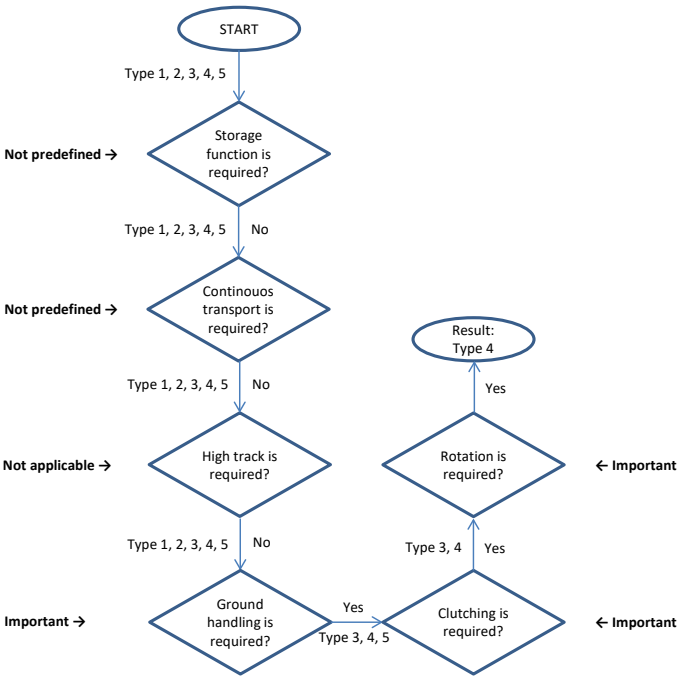

Fig 6. Equipment selection algorithm for the exclusion of machine types at the example workplace

As you can see on Fig. 6, the algorithm results articulated robots as handling machine for the example workplace. Of course, if we describe more details for the workplace, we can get other machines or handling systems as a result. Our objective was only the demonstration of the operation of the algorithm.

6. SUMMARY

To increase the efficiency of the production processes advanced manufacturing technologies and handling solutions are required. This paper presented an overview about the planning process of the material handling machines, especially for the production workplaces. There are many material handling machine types, so the equipment selection process is a crucial part of the planning procedure.

The objective of our research is to describe a general selection algorithm; however, it is not an easy task, because of the large differences among the workplace structures and handling solutions. To reach our target, we follow a step-by-step concept, in which we will define special algorithms for the individual phases used for different example workplaces and after it, in the knowledge of the specific methods we can build a general algorithm.

As the first step of this concept, in this paper we described an algorithm to realize the exclusion phase of the equipment selection process. To show the applicability of the concept an example was also presented.

As a result we can say, that the algorithm resulted a suitable machine type. Of course, if we describe more details for the workplace, we can get other solutions as result, but in this paper our objective was only the demonstration of the operation of the algorithm.

The results presented in this paper are only a small part of the research, and the consequences valid for only the actual example, the actual parameters of the workplace environment can modify the application characteristics of the selection algorithm.

The next step of our research will be a detailed analysis of the example workplace to describe a general structure for the exclusion algorithm and the description of the relation to the second selection phase. Of course, the operation of the selection algorithm must be checked by advanced computer methods (e. g. simulation [14], optimisation [15]).

REFERENCES

[1] Mark B. G., Rauch E. & Matt D. T. (2022). Systematic selection methodology for worker assistance systems in manufacturing. *Computers and Industrial Engineering*, 166, art. no. 107982. https://doi.org/10.1016/j.cie.2022.107982

[2] 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

[3] Michal D., Lecky S., Kostal P. & Vaclav S. (2019). Welding workstation planning with use of CAD software and simulation. *Lecture Notes in Mechanical Engineering*, 97-105. https://doi.org/10.1007/978-3-030-18789-7_9

[4] Telek, P. (2022). Material handling model of production workplaces. *Advanced Logistic Systems - Theory and Practice* 16(1), 51-62. https://doi.org/10.32971/als.2022.005

[5] Dilworth, J. B. (1979). Prod*uction and Operations Management: Manufacturing and Nonmanufacturing.* Random House, New York, Toronto https://doi.org/10.1088/1757-899X/448/1/012018

[6] Telek, P. (2022). Role of workplace handling parameters in the material handling equipment selection. *Journal of Production Engineering* 25(1), 53-58. http://doi.org/10.24867/JPE-2022-01-053

[7] Telek, P. (2022). Comparison analysis of material handling solutions of production workplaces. *Rezanie I Instrumenty V Tekhnologicheskih Sistemah* 97(1), 3-20. https://doi.org/10.20998/2078-7405.2022.97.01

[8] Telek P. (2016). Material flow relations in the design process of materials handling. *Advanced Logistic Systems - Theory and Practice* 10(1), 53-64.

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

[10] Telek, P. (2014). Application of device-preselection for discontinuous unit handling. *Advanced Logistic Systems - Theory and Practice* 8(1), 93-102.

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

[12] *Plant Simulation official website*. Retrieved from https://www.plm.automation.siemens.com/store/en-nl/plant-simulation

[13] *Laboratory of Flexible Manufacturing Systems*. Institute of Production Technology of the Slovak University of Technology in Trnva. Retrieved from https://www.stuba.sk/english/science-and-research/other-research-centres-and-laboratories/laboratory-of-flexible-manufacturing-systems.html?page_id=10622

[14] Tamás, P. (2017). Decision Support Simulation Method for Process Improvement of Intermittent Production Systems. *Appl. Sci.*, 7(9), 950. https://doi.org/10.3390/app7090950

[15] 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