

MATERIAL HANDLING MODEL OF PRODUCTION WORKPLACES

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Abstract: Nowadays, most of the manufacturing procedures use different workplaces to realize given production steps. At the production workplaces different material handling solutions are applied, however the selection of the suitable handling equipment is not optimized and based on experimental knowledge. The research presented in this paper targets to develop a model which can help to select the most suitable material handling equipment for different production workplaces. This paper gives an overview about the types of the workplaces in the aspects of material handling, the principals of the model building process, the structure of the possible model versions and presents an example for the applicability of the conception.

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

1. INTRODUCTION

The role of the industrial processes is more and more important in the everyday life of people living in developed societies. We use many items produced in different companies, and the success of them is largely influenced by their cost and quality. To reach the suitable consumption parameters, companies have to use efficient production processes. Nowadays, most of the manufacturing procedures use different workplaces to realize given production steps, so their structure and operation parameters are very important factors.

There are many workplace types applied in production processes which use different internal material handling solutions. In most of the cases, the selection of the applied handling equipment used for internal workplace handling is not optimized and based on experimental knowledge. The research presented in this paper targets to develop a model which can help to select the most suitable material handling equipment for different production workplaces, involves the internal and external aspects.

This paper gives an overview about the types of the workplaces in the aspects of material handling, the principals of the model building process and the structure of the possible model versions. To show the applicability of the conception an example will also be presented.

2. MATERIAL HANDLING IN WORKPLACES

Production workplace means an object where a given production operation is realized. There are many types of workplaces which can be different in physical, production, handling, or other aspects [1], but the differences are important for this research if they significantly influence the material handling parameters.

The workplace handling is the smallest part of the material handling system of a manufacturing process. It involves only the handling of the input materials and elements, the internal handling of the elements and the processed units and also the handling of the output products of a given workplace.

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There are many types of workplaces, but all of them contain the same physical area types (Fig. 1), where the different handling activities must be realized:

- production area (involving production activities),
- operator area (involving the handling lines),
- storage area (involving the input, output and other storage points),
- loading area (involving the transfer activities).

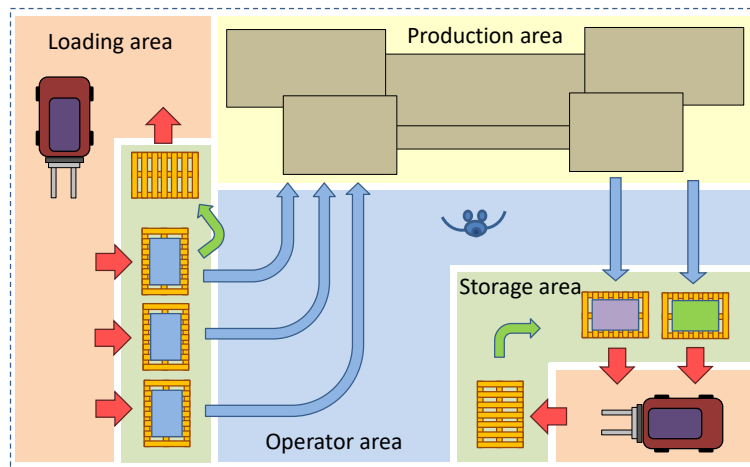


Fig 1. Parts of the workplace area

The number, size and location of the individual areas can be different depending on the characterisation of the given workplace. Adding vertical sizes to the workplaces areas, we can define a prismatic volume which limits the handling movements and involve all related activities (see Fig. 4).

In the aspect of the handling process five different activity types can be defined:

1. Entrance of the elements into the workplace.
2. Moving of elements from the entrance point to the starting point of the production process.
3. Moving of processed units among the production activities.
4. Moving of finished products from the finishing point of the production process to the exit point.
5. Exit of the finished products from the workplace.

The different steps can be realized individually or combined with others and of course the number of the internal production points can be different.

Important question, how can we describe and examine the material handling process of a production workplace. To find answer to this question, we analyse the international literature, based on the Scopus database.

During the research, until May 2022, 887 matches were found in the Scopus database related to the search: TITLE-ABS-KEY (workplace AND material+handling). Because the research deals only with the production related aspects, the search were limited to the Engineering field (TITLE-ABS-KEY (workplace AND material+handling) AND (LIMIT-

TO (SUBJAREA , "ENGI")), which resulted 309 papers. Fig 2 contains the distribution of the papers among the most frequent keywords used.

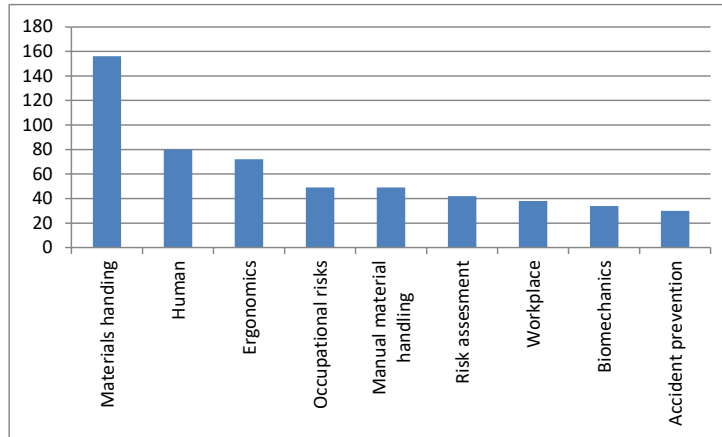


Fig 2. Distribution of the most frequent keywords of the publications

As the research targets to find suitable material handling machine for the internal workplace handling tasks, so I excluded all papers which related to the manual material handling topics and other human related aspects (e. g. health, safety, risks). After this exclusion 92 documents remained.

Most of the publications (26%) deal with one given handling machine type (e. g. welding robot [2]) used in workplaces, 20% of them have general topic about the workplaces (e. g. [3]), 15% related to the increasing possibilities of the workplace performance (e. g. [4]), 14% presents solutions for extended handling among several workplaces (e. g. [5]) and 16% related to other topics (material aspects, special applications, etc.). Only 5 papers deal with real workplace planning, where the authors look for handling solutions for given workplaces activities (Fig 3).

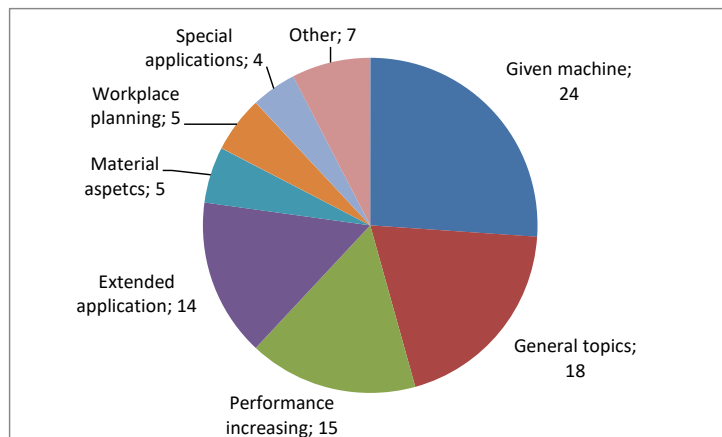


Fig 3. Distribution of the handling equipment related publications

Paper [6] gives an overview about the component handling methodology involving the workplace handling solutions; paper [7] presents the types of the production workplaces and their planning methodology. The other three papers present a certain aspect of the workplace handling, paper [8] deals with the role and importance of the input and output stores of the workplaces, paper [9] is related to the automation pattern of the workplace handling and the last one [10] presents an example for the creation of the workplace handling.

Summarising the related literature research in the Scopus database, we can state that no one of the publications presented a general model for the handling process of workplaces.

2. INTERNAL HANDLING MODEL OF WORKPLACES

As there is no applicable model in the international literature, a new model has to be created, which is suitable for the description of the handling process of production workplaces.

Based on the workplace area, presented in Fig. 1, a material handling model can be formed. In most of the cases, the model does not contain the loading area because it belongs to the external transport line. In the model, used in the research (Fig. 4), external handling equipment transfers the input elements to the entrance and the output elements from the exit point in the storage areas.

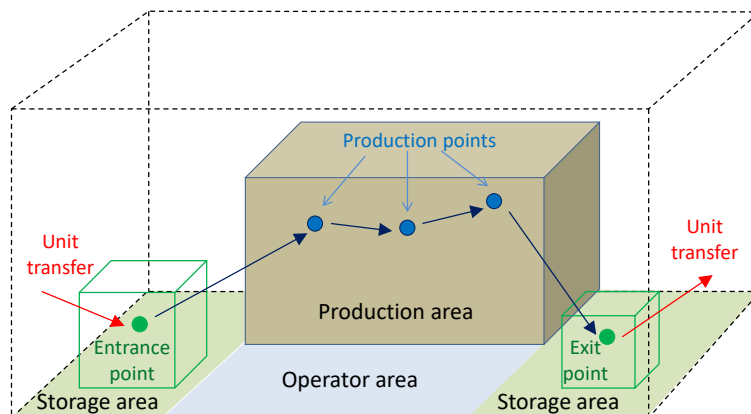


Fig. 4. Unit handling model of workplaces

In the aspect of the material handling equipment used in the workplace we can apply different approaches, where the activities are realized by

- independent devices for the external (entrance and exit points) and internal handling,
- only external handling machines which also realize the internal handling tasks (entering into the workplace),
- only internal handling machine which is able to realize the loading from/to a transport machine.

All three variations have important role in workplace handling, but in this paper only the first approach will be analysed focusing to the internal handling processes.

As Fig. 4 shows, the internal handling process is a chain of different handling operations, which starts at the entrance point, involves different production points (operation, picking and storage points) and is stopped at the exit point.

Based on the workplace and unit parameters, the general model presented on Fig. 4 can be simplified and used for certain cases (Fig. 5):

- one-point model (one external handling machine, entrance, exit and operation point are the same, typical application for large units, without storing),
- two-point model with two sides (different internal and external handling machines, entrance and operation point is the same, internal handling among the operation and exit points, e. g. cutting),
- two-point model with one side (different internal and external handling machines, one operation point, entrance and exit point is the same, internal handling among the operation and entrance/exit points, applied for low production frequency),
- three-point model (different internal and external handling machines, one operation point, different entrance and exit points, internal handling among the operation and entrance/exit points, the most often used variation).

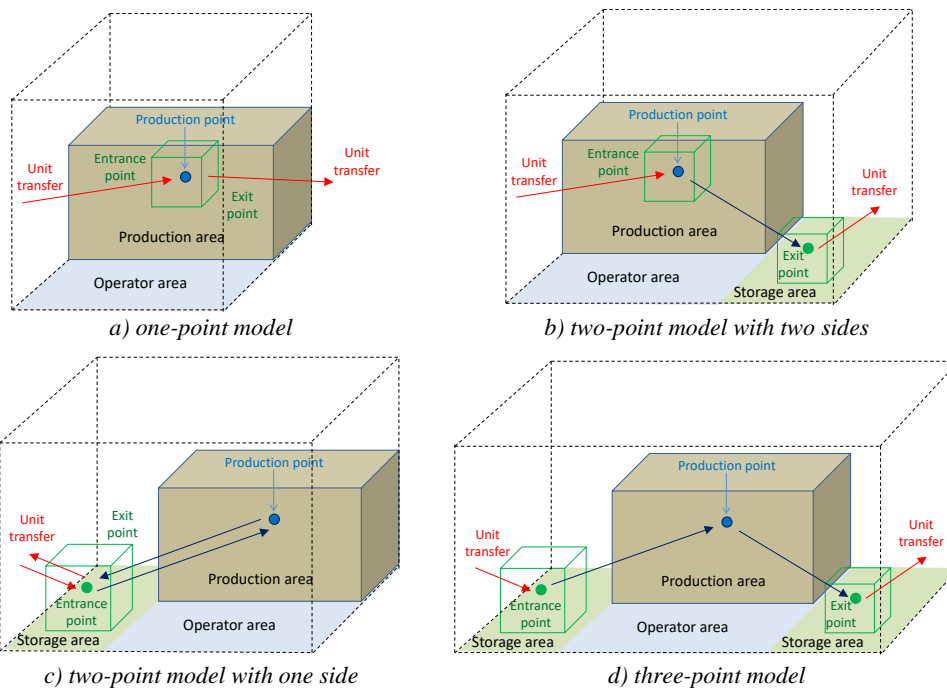


Fig. 5. Unit handling model variations

In this paper the general model will be applied for the selection of material handling equipment used for the internal handling processes.

3. EQUIPMENT SELECTION BASED ON THE INTERNAL MATERIAL HANDLING MODEL

During the equipment selection process [11] we have to use a model variation which can describe the real handling activities. Applying the material handling model presented on Fig. 4 enables to create infinite material handling process variations, but only some special variations are interesting for the research. To find the suitable model variations, the applicable handling machines and their operation characteristics must be described.

There are many machines which can be used for internal workplace handling processes, but they can be separated into typical groups depending on their handling environment [12]. We can apply different approaches to define the related groups, we are using the next categories:

- single workplace handling,
- multiple workplace handling,
- external and internal workplace handling,
- only external handling.

Single workplace handling means those solutions, which can be efficiently applied for one workplace, without any limitations (e. g. robots). Machines used for multiple workplace handling can be applied for single workplaces, but their application is efficient only for multiple workplace handling or large products (e. g. bridge cranes). The external and internal workplace handling category contains machines which can be used for long transport of the goods and have workplace handling solutions (e. g. pneumatic transport), however their limitation to one individual workplace is not efficient. Some material handling equipment is served only for external workplace handling (e. g. pallet cars), so they are not suitable for internal handling.

In this paper only the solutions belong to the first category will be analysed (involved into Table I). Many factors influence the applied material handling machine (production parameters, unit characterisations, etc.), however our research deals only the effects of the physical environment, so we take them into account [13].

Table I.
Handling parameters of material handling equipment used in workplaces

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

The first possibility is the use of different conveyor types for the internal handling, which are the simplest but the most limited solutions. They are similar physical handling

characterisation, only the operation is different (e. g. the roller conveyor sections can be easily operated individually, for belt conveyor types it is much harder). In this case the different production activities (production points) must be placed along the conveyor line, which has mainly linear, horizontal line sections and the vertical moving is limited.

The running hoist moves also along a line, but the vertical moving (lifting) is unlimited between the floor level and the line track. As the cranes use upside gripping, so the reaching direction is limited.

Another handling equipment type is the linear manipulator, which can be used for any kind of handling tasks, however, all of them built for a given handling procedure, so the changing in any parameter is not possible. The handling parameters of this equipment are depends on the structure of the device (e. g. a rotation arm move only along an arch line), universal application is not possible.

Jib cranes have different handling environment, because it can move in two different directions (rotation and radial movement) and can lift in any point of the serving area. As it is also a crane the vertical moving and the upside reaching are also evident.

The most often used and most expensive devices for the internal workplace handling are the articulated robots, which are universal machines for the internal workplace activities. There are different types of them and their application environment is depends on their structure, we take only fix mounted articulated robots into consideration in our research. The handling area of fixed robots is a part of a given sphere, because it has one rotation centre. The most important handling parameters are the unlimited rotation and linear moving within the predefined sphere volume and the multi-directional reaching of the pieces.

If we can draw the production points and the moving lines of a given workplace, we can select the suitable handling devices and analyse their efficiency. The next chapter presents an example for the using of the above mentioned concept.

4. EXAMPLE FOR THE INTERNAL HANDLING EQUIPMENT SELECTION FOR WORKPLACES

For the demonstration of the internal handling equipment selection concept, an example was created which represents a general production workplace (Fig. 6).

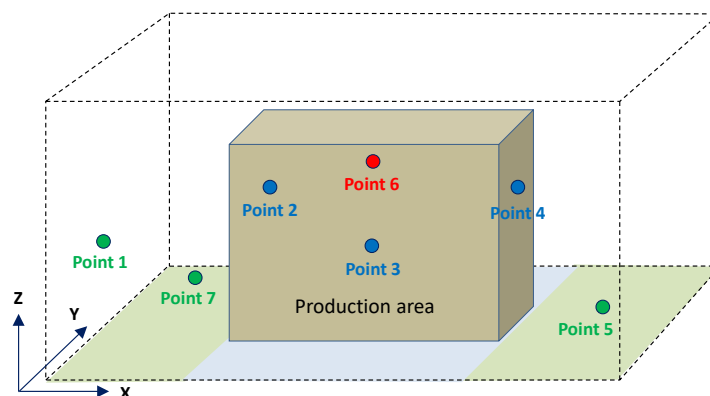


Fig. 6. Structure and handling points of the example workplace

In the example workplace, 7 handling points were defined; their physical and functional data are involved into Table II.

Table II.
Data of the predefined handling points of the example workplace

Handling points	Coordinates			Function	Location to the production object
	X	Y	Z		
Point 1	1	1	1	Entrance	Left side
Point 2	3	2	1,5	Production	Front side
Point 3	4	2	1	Production	Front side
Point 4	6	2,5	2	Production	Right side
Point 5	7	1	0,5	Exit	Right side
Point 6	4	3	2	Production	Back side
Point 7	1	3	0,5	Exit	Left side

To analyse the effects of the point locations for the equipment selection, 4 moving alternatives were linked among the handling points (see Fig. 7).

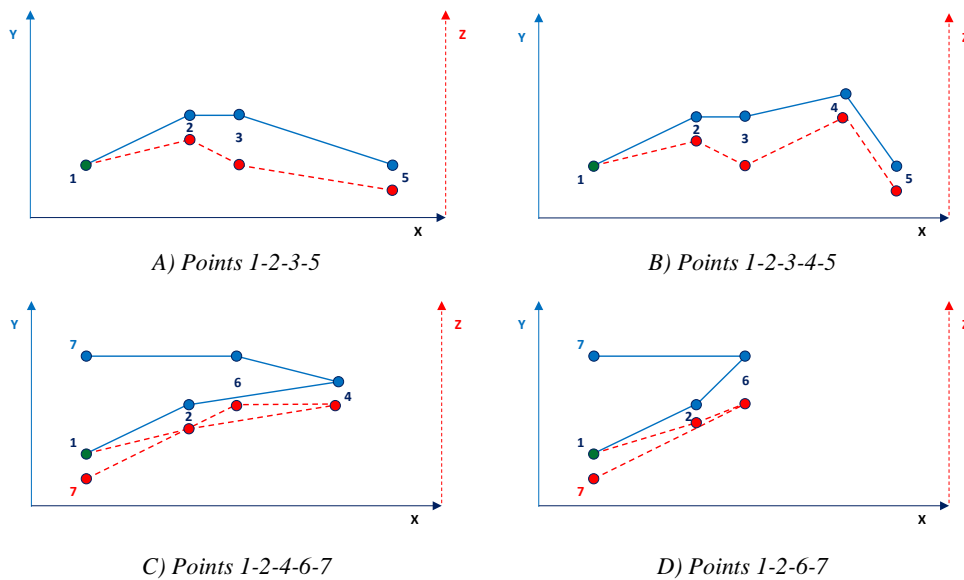


Fig. 7. Horizontal and vertical moving lines of the alternative versions

In this analysis we took that machines into consideration which are involved into Table I, except the linear manipulators, which can be very different. After this reduction we have 4 different solutions for realizing the handling activities of the example workplace: conveyors, running hoists, jib cranes and articulated robots.

In case of Variation **A** (1-2-3-5), different conveyors, running hoists and wall mounted jib cranes (with 4 meter-long jib) easily usable for the workplace handling, and also two fix mounted articulated robots (with 2 m radial movement) located as presented in Fig. 8.

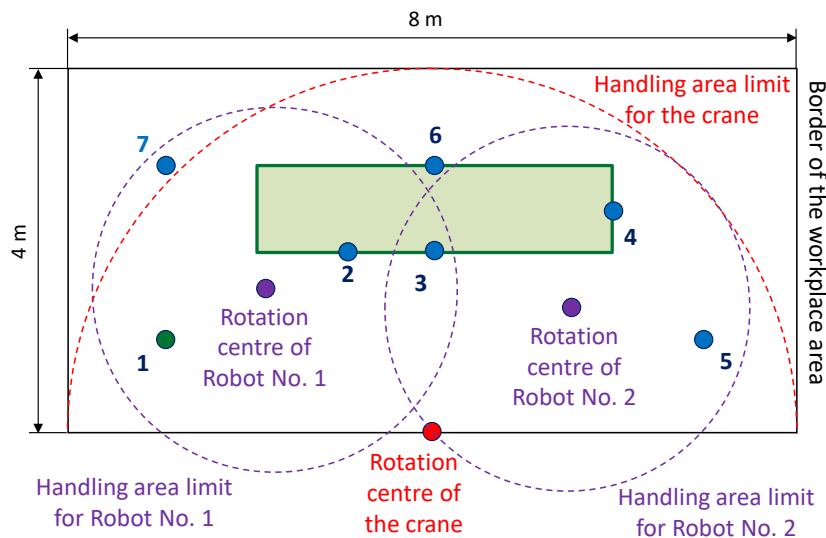


Fig. 8. Handling areas of the jib crane and the robots

Variation **B** (1-2-3-4-5) also suit for the running hoists and jib cranes, but the using of conveyors is not acceptable, because of the sudden and frequent changing of the vertical height (see Fig. 7/b), and the location of Point 4 at the right side of the production machine, which requires complex line structure. This is also true for the robots, where the body of the production machine can disturb the reaching of Point 4 (Fig. 8).

Another handling procedure requires in case of Variation **C** (1-2-4-6-7), where the moving line turn around the production machine, so the building of a conveyor line is a suitable solution again and the vertical moving also not so high. However the application of a running hoist is not suit, because the line tracks in generally need higher radius for the line arch. Robots are also not applicable, because Point 6 cannot be reached from the front side. In case of jib cranes, the length of the jib is limited (max. 4 m), because it cannot be projected over the workplace border, so Point 7 cannot be reached. It is possible to change the location of the centre of the crane, but the best if it is mounted on the wall or a construction column.

The facts mentioned at the previous variation are also true for Variation **D** (1-2-6-7), however the application of the conveyors is problematic, because the length of the moving between Points 2 and 6 is too long. The best solution is a small jib crane (with 2 meter-long jib), but located closer to Point 7, near the production machine (Fig. 9).

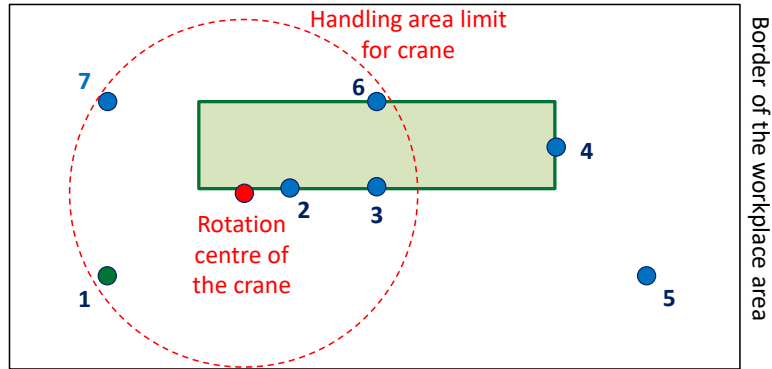


Fig. 9. Modified location of the jib crane for Variation D

Summarising the results of the material handling equipment selection procedures for the different moving alternatives (see Table III.), we can state that there are applicable equipment type for all variations, but in some cases we can use the machines with less optimal parameters.

Table III.

Suitability of the different material handling equipment for the moving alternatives

Moving alternatives	Conveyors	Running hoists	Jib cranes	Articulated robots
Variation A	Suit	Suit	Suit	2 robots
Variation B	No	Suit	Suit	No
Variation C	Suit	No	No	No
Variation D	No	No	With small jib, located near the machine	No

As in some cases, there are different material handling solutions usable for the actual model variation, further analyses is required to compare the possibilities. For this purpose different simulation [14] and optimization [15] methods can be applied.

5. CONCLUSIONS

At the production workplaces, different material handling solutions are applied; however, the selection of the suitable handling equipment is not optimized and based on experimental knowledge. At the beginning of the research, we targeted to develop a model which can help to select the most suitable material handling equipment for production workplaces.

This paper gives an overview about the types of the workplaces in the aspects of material handling, describes the principals of the model building process and the structure of the possible model versions. In this paper only the internal handling aspects were taking

into consideration, where the focus was on the structure of the internal handling points and their connections, looking for the best fit handling solution.

The last chapter of the paper contains an example for the handling variations of a given workplace, and presents the result of the equipment selection process.

Summarising the results of the research presented in this paper, we can state that the analysis of the workplace and the handling equipment parameters can largely make quicker the equipment selection process.

Of course, the result presented in this paper is only a small part of the research related to the role of the production workplaces in the material handling equipment selection process, the next steps will be the comparison of the efficiency of the suitable internal handling solutions.

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