UDC 658.511 **doi: 10.20998/2078-7405.2022.97.01**

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COMPARISON ANALYSIS OF MATERIAL HANDLING SOLUTIONS OF PRODUCTION WORKPLACES

Abstract: *Production and assembling workplaces can be different in manufacturing and physical environment characterisations, or internal structure, involving the applied material handling solutions, which must be suited to the workplace specifications. The general objective of my research is to develop a model which can help to select the most suitable material handling equipment for production workplaces. The topic presented in this paper deals with the comparison of the different handling solutions. After the overview of the material handling model and the handling equipment selection procedure of production workplaces, a comparison analysis of the applicable handling solutions will be introduced. The last chapter of the paper contains an example for the comparison analysis of a given workplace.*

Keywords: *workplace handling; modeling; material handling equipment; comparison.*

1. INTRODUCTION

The role of the industrial processes is more and more important in the everyday life of people living in everywhere in the World. We use many items for different purposes, most of them are manufactured in special workplaces, so their structure and operation parameters are very important to reach the suitable consumption parameters (quality, price, etc.). Production and assembling workplaces can be different in manufacturing and physical environment characterisations, or internal structure, involving the applied material handling solutions, which must be suited to the workplace specifications. The general objective of my research is to develop a model which can help to select the most suitable material handling equipment for production workplaces. The topic presented in this paper deals with the comparison of the different handling solutions.

This paper presents the material handling model of production workplaces, an overview about the handling equipment selection process for workplaces and the comparison analysis of the applicable handling solutions. To show the applicability of the conception an example will also be presented.

2. MATERIAL HANDLING IN WORKPLACES

2.1. Production 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].

In the international literature, we can find different categories for workplaces based on manufacturing activities, product types, workplace elements, workplace structure, working environment, job characteristics, manufacturing characteristics, operation types, etc.

A **manufacturing activity** means an operation group realized on one element of a production workplace, which can be very different in complexity [2]. There are lot of activities using in a production process depend on the manufacturing characteristics (assembling, cutting, filling, pushing, etc.). A production procedure of a given **product type** requires many different manufacturing activities and working environment [3], and the linking of the activities also determines the workplace parameters (e. g. parallel or linear processes). All manufacturing activity must be realized on suitable **workplace elements**, which also can be different, depend on the applied activity types (manufacturing machines, assembly tables, etc.) [4]. The **workplace structure** defines the relations among the different workplace elements [5], involving the manufacturing and handling activities (U-shape, linear, parallel, etc.). The **working environment** affects the human operators and the machines which realize the activities [6], the most important influencing factors are the temperature, noise, lighting and other parameters (e. g. social and comfort environment). Another important category is the **job characteristics**, which depends on the job type of the human or machine workforce (e. g. baker, painter, woodworker) [7]. The widest category is the **manufacturing characteristics** [8], which involves all production and service sector of the economy and define only some main characteristics (e. g. textile industry, transportation). The **operation type** is also an important parameter because different workplaces must be used for manual, mechanized, full automated or assisted systems [1].

If we build a workplace, all categories must be taken into consideration, however; this research deals only the material handling aspects of the workplaces, so only the types which significantly influence the material handling parameters are important from this aspect.

2.2. Material handling model

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 tasks suited to certain logic and take them together into account, we get material handling process as a result [9]. 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. It involves only the handling of input materials and elements, the internal handling of elements and processed units, and the handling of output products of a given workplace [10]. Realization of the workplace handling depends on the physical environment, which contains different functional areas: production, operator, storage, loading, transport, inspection, etc. areas [6], but in this research the model defined in paper [11] was use taking 3 different areas into account: production, operator and storage areas.

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 [11].

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 [11], which involves the related handling activities as individual points (Fig. 1).

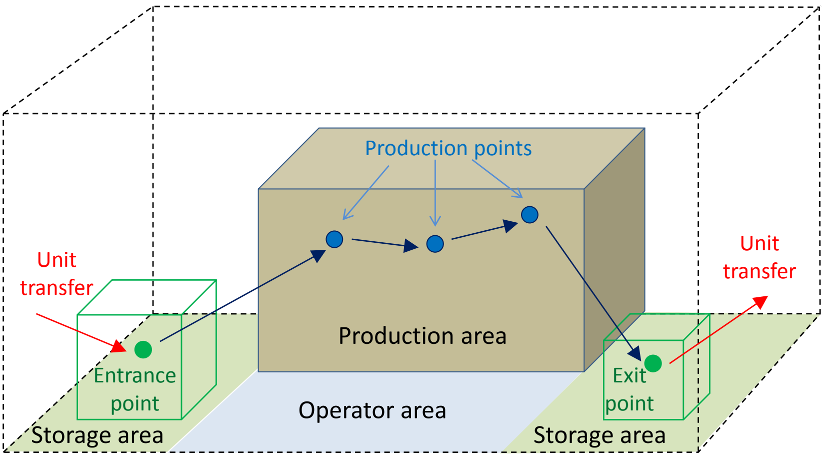


Figure 1 – Simple handling model of workplaces [11]

As Fig. 1 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 [10]).

3. MATERIAL HANDLING EQUIPMENT SELECTION FOR WORKPLACES

3.1. 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 [12]. 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) [13]. The application of this approach is limited because of the complexity of the material handling systems and the lack of reference handling systems (general databases).

The task-based approaching [14] follows a given or iterative order of different planning subtasks. The optimal solution for the task-based approach, if we realize all required subtasks together, in a predefined order. This integrated planning concept cannot be used in generally, because of the volume, complexity and iterative manner of the different tasks. In the practice, it can be solved only at simple planning cases [15]. Other possibility is the simplification of the integrated planning process to single-task-planning, augmented-planning or complex-planning [9].

There are many solution techniques and methods to solve single planning tasks [16], 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 depends on the involved subtasks [17].

According to the increasing of the computational performance and to the development of optimization 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 easily accept its using [18]. To avoid this 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].

We can see that the planning of material handling is a complex and hard process, but the equipment selection is a very important element of the traditional, the integrated and the process-based planning. In our research the focus is on the application of the equipment selection for the production workplaces.

3.2. Material handling equipment selection

Main objective of the equipment selection is to find the best material handling solution for all handling relations. 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 [19]. 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. [14].

At the other side the handling machines also have different parameters (e. g. capacities, velocities, loading and transport capabilities) which must take into consideration during the selection process [20].

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 [20]. 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 (goods parameters, task parameters, etc.) and not numerical limitations (object parameters, track parameters, etc.). Numerical parameters are the bases of the analytic design process, their values can be different for the individual materials handling machines (route length, energy consumption, etc.).

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

In this paper only the third phase is analysed comparing the applicable material handling machine types.

3.3. Equipment selection for workplace handling

The workplace handling is separated into two different 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 off goods 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. 1). There are three different possibilities for the realization of the handling process in the aspect of the workplace handling machine types:

1. Using separate machines for the internal and external handling
2. Using only an external handling machine which also realizes the internal tasks (e. g. forklift)
3. Using only an internal handling machine which can handle the goods on the entrance and exit points, the external machine is only a transporter without loading possibility (e. g. pallet car)

There are different equipment selection steps for the above-mentioned cases, in the first case two independent or parallel procedures must be applied, in the other two situations one complex selection process is required, but in the third case in two parts (the internal handling is the dominant).

In this paper we describe a general equipment selection procedure which can be applied in all three cases using suitable parameter set.

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

1. Exclusion of the solutions which are not suitable for workplace handling of the given goods [11]
2. Taking the physical parameters and manufacturing environments of the workplace into account (e. g. safe mounting of crane structure, see [10])
3. Comparison of the applicable handling solutions

This paper deals only with phase 3, where the theoretical principles and methods, or rather the practical application will be presented.

4. COMPARISON ANALYSIS OF HANDLING MACHINES FOR WORKPLACES

After the first two phases of the selection procedure, we can get three different results: only one machine type is usable, there are more than one machines which is applicable or there is no suitable machine type for the tasks. We can use the third phase in all three cases, but the aims are different. If we have only one usable machine, the methods applied for the comparison will be the bases of the dimensioning process, or the possible subtypes can also be compared. In case of more than one suitable machine types, the comparison procedure is obvious. If we could not find any suitable machine, we must modify the handling parameters and make new handling environment for repeating the first two phases. For the modifications, we can also use the mathematical methods of the comparison phase.

The comparison procedure is based on one or more numerical parameters in every case, the most important ones are 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.

4.1. Comparison methods

The production workplaces and the material handling solutions can be very different, so lot of methods can be used for the comparison analysis [21]: Analytic methods, Mathematic software, Optimisation methods, Simulation methods or Virtual reality software.

For simple comparison we can use **analytic methods** to find the best handling solution, but they can be used only for well determined, special cases (e. g. optimization of transport capacities).

Much more exact comparison can be realized by the using of **mathematic software**, which are also limited in task types, but they can analyse much more versions. Important conditions of their application are the mathematical descripability (suitable models and formulas) and the knowledge of the suitable software (MathCAD [22], MatLab [23], etc.).

Optimisation is a new and effective technique to find the best solution for a given task or process. During the optimisation process we create different variations and analyse their efficiency to find an optimal solution. The increasing of the computing capacities and calculation speed of the computers resulted many new methods and algorithms in the practice [24], but this device mainly suit for increasing the operation efficiency.

Simulation methods are the most often used devices for the comparison of different solutions. As this paper will use one of them in the next chapter so their description can be found there.

Another possibility for the comparison of handling machines is the using of **virtual reality software** (VR). There are different definitions for virtual reality [25], but in the aspect of the planning of material handling we can define virtual reality solutions as devices for presentation of simulated 3D objects and their environment. In practice, VR solutions can be used for planning or teaching of handling processes. In the aspect of the equipment selection, we can use them for virtual comparison of different machines and their behaviours.

4.2. Simulation methods

Simulation is a device to model real processes and evaluate their states, changings and other process elements [14]. Simulation methods usually applicable for modelling of given processes, however they can be adapted for different similar process variations setting their parameters in.

Types and characterisations of the applied simulation process depend on the model, the calculation schemes, the environment and the parameters are taken into account. Based on the large variation of the methods, a huge number of simulation software has been developed during the last decades.

There are also several simulation methods used for the material handling and logistic processes, modelling different elements of the handling procedure [26]. The main application field of simulation software in material handling is the examination of the operation and taking the effects of stochastic changing parameters into consideration. Another important application of the simulation is the preliminary analysis of the designed machines and systems, involving the comparison of alternative solutions.

The most often used simulation methods in material handling are PlantSimulation [27], FlexSim [28], ExtendSim [29], Enterprise Dynamics [30], etc.

Demonstrating the comparison process of the handling variations, a simulation analysis was made using Technomatix Plant Simulation software [27], presented in the next chapter.

5. SCENARIO FOR THE COMPARISON ANALYSIS

5.1. The example workplace

To demonstrate the comparison phase of the material handling equipment selection process, an example production workplace was created. In the example, the model described in [10] was applied with six handling points presented in Fig. 2 and 3, their physical and functional data are involved into Table 1.

Table 1 – Data of the predefined handling points of the example workplace

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

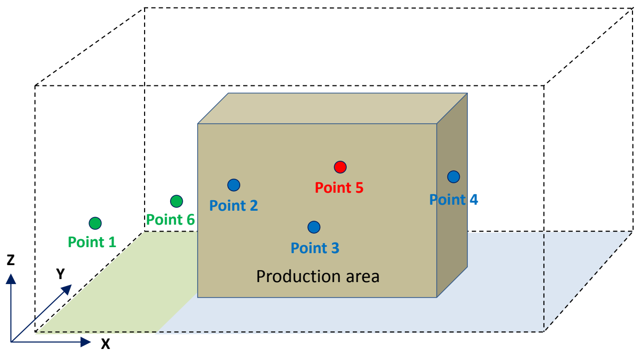


Figure 2 – Structure and handling points of the example workplace

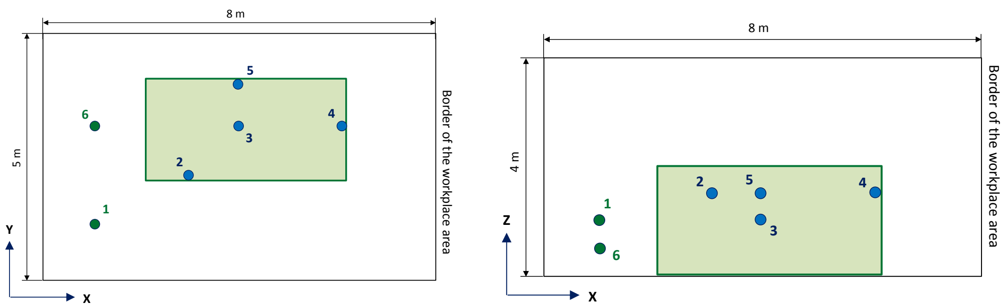


Figure 3 – Horizontal and vertical locations of the handling points

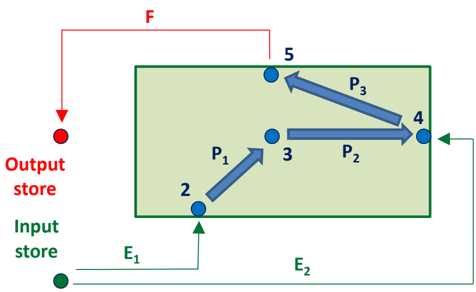


Figure 4 – Manufacturing operations and material flow of the process
(E_1, E_2 –elements transport, P_1, P_2, P_3 –processed units handling, F –finished units transport)

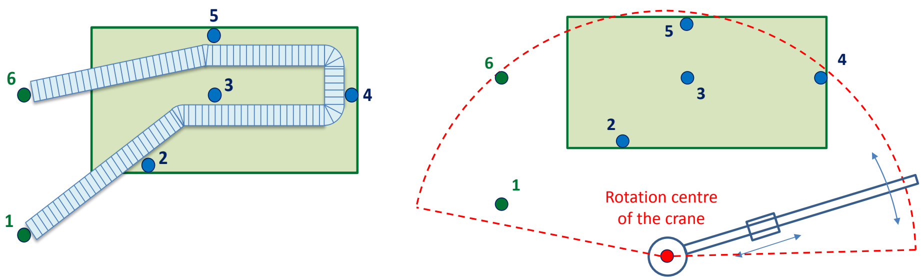
In the production procedure two different elements (single pieces) enter into point 1 in unit loads and are transported individually among the other handling points. Element 1 starts the process in Point 2 as the main part, then moves into Point 3 and 4. Element 2 starts in Point 4 where it is built into the main part. After the union the main part moves to Point 5 and leaves the workplace at Point 6, in another unit load (see Fig. 4).

5.2. The suitable handling machines

Based on the analysis in [10] there are 5 applicable material handling equipment types which suitable for internal handling of small, individual production workplaces (conveyors, running hoists, linear manipulators, jib cranes and articulated robots).

After the previous selection based on the exclusion and limitation type parameters, articulated robots are not suitable for the example because it is hard to reach 3 different sides of an area from outside direction. Linear manipulators are also not so efficient, because they have complex and expansive structure and operation which is not required in this simple case. Running hoists are suitable, however the alternate moving along a long line (near 12 m) is not effective (individual transport of the two elements and the main part). The real solutions are the using of conveyors and jib cranes.

Different conveyor types can be considered for the workplace handling, but the chain driven variations (e. g. trolley-, tow-conveyors) are too complex for small areas. At single piece handling the most usable types are the roller and belt conveyors, however, the frequent changing of the directions can be better realized by rollers (Fig. 5.a).



a) Roller conveyor line b) Wall-mounted jib crane

Figure 5 – Handling machine variations

The other possibility is the using of jib cranes, where the workplace determines the application of a wall-mounted crane with a 4-meter-long jib. The location and handling area of the crane are presented in Fig. 5.b.

In the simulation analysis the parameters of these two machines and the manual handling as a reference will be compared (Version A: conveyor, Version B: jib crane and Version C: manual handling).

5.3. The simulation model

To realise the handling process, a simulation model was made in Technomatix Plant Simulation environment, which contains different simulation elements for the handling variations suited to the applied software: production stations, transfer objects, transport line sections, sources and drains (input and output), handling solutions (conveyors, cranes, human resources), buffers and stores, etc.

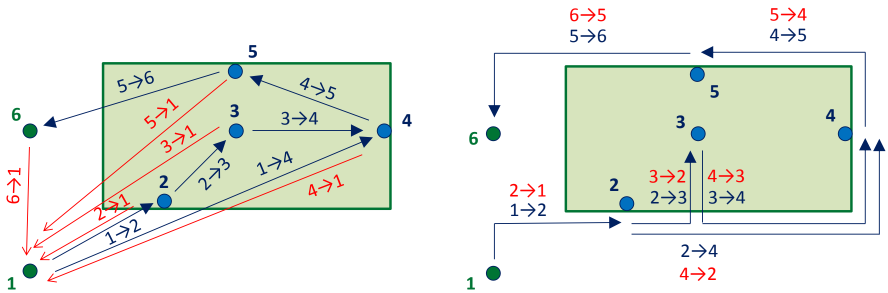
4 production stations were applied at points 2, 3, 4, 5 (point 4 is an assembling station) for all cases, the handling variations differs mainly in the transfer specifications (represented in the loading time), the number and length of the transport lines and some specification of the handling solutions. Table 2. presents the details of the basic simulation model.

Table 2 – Base data of the simulation model

MODEL PARAMETERS	Version A	Version B	Version C
Handling solution	Roller conveyor	1 jib crane (4m jib)	1 human person
Process times for all stations	120 s	120 s	120 s
Loading operations	Automatic transfer	Lifting and clutching	Manual handling
Loading times for all operations	10 s	10 s	10 s
Transport operations	Continuous moving on conveyor sections	Jib rotation + hoist movement	Manual transport
Transport speed	0,5 m/s	1 m/s	1 m/s
Transport sections	5	11	6+6
Sources	1 input store	1 input store	1 input store
Drains	1 output store	1 output store	1 output store
Internal stores	Only buffers	Only buffers	Only buffers

The number and length of the transport sections of the handling solutions depend on the applied machines and strategies. In case of the roller conveyor, only 5 line-sections (1→2, 2→3, 3→4, 4→5, 5→6) were used which link the stations directly and the 1→2, 2→3 and 3→4 sections were used together for the transport of the elements from the source store to station 4 (see Fig. 5.a).

For the jib crane, passive moving sections also must be defined beside the active transport phases, because the crane must change its position among the loaded activities. The number of the active sections is 6 (1→2, 2→3, 3→4, 4→5, 5→6, 1→4), the theoretical number of the empty movement sections is 13, however it depends on the working strategy, in this case a simple strategy is applied with 5 empty movements (2→1, 3→1, 4→1, 5→1, 6→1). Fig. 6.a presents the applied movement sections for the crane.



a) Crane handling b) Manual handling

Figure 6 – Transport lines for the workplace
(blue lines –transport sections, red lines – empty movement sections)

There are also exist passive movement sections at human handling solutions, however the number and lengths of them depend on the handling specifications of the workplace. In this case the input and output points are separated, so the human worker must move along an open line and use the active sections for the empty returns (see Fig. 6.b). Because of it, the 5 active sections are obviously (1→2, 2→3, 3→4, 4→5, 5→6), but one relation (1→4) is special, because in the sections 2→3 and 3→4 the worker must step into the production area, which is not needed for the 1→4 relation. To solve this problem, a section 2→4 was created and used sections 1→2 and 2→4 together for transport the elements in relation 1→4. In case of the passive movements the worker must use the active sections in invert directions.

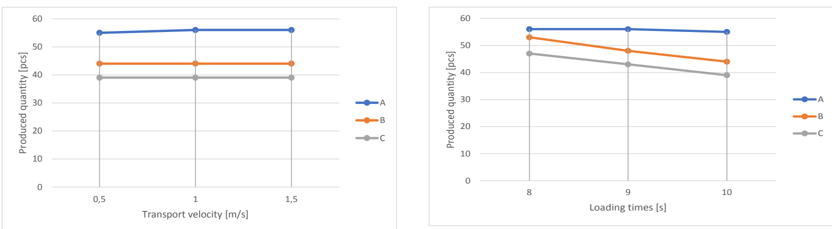
5.4. Simulation results of the versions at the basic model

After running the simulation for all versions with the basic data, the results of the different handling solutions can be compared. During the research the production performance, the transport capacities and the waiting times were used as comparison parameters (Table 3).

Table 3 – Simulation results of the different versions

COMPARISON PARAMETERS	Version A	Version B	Version C
Simulation time [min]	120	120	120
Produced quantity [pcs]	55	44	39
Total waiting times of the handling [%]	72	0	0
Average waiting times of the stations [%]	3,3	20,4	27,9
Total transport distance [m]	952	1412	1945
Average buffer levels [pcs]	1,1	2,5	2,5
Maximum buffer level [pcs]	2	7	7
Loaded handling routes [%]	28	51	50,6
Rise time [s]	603	760	809
Cycle time [s]	120	148	164

The most important cause of the differences among the versions is that at the continuous handling the loading and transport operations are independent from each other because the transport can be parallel. At discontinuous handling the operations directly affect each other in case of one handling machine. If we change the basic handling parameters (loading times and transport velocities) the results will be different (Fig. 7).



a) handling velocity b) loading times

Figure 7 – Effects of the parameters to the production performance

Fig. 7.a presents that the transport speed has no significant influence on the production process, in all analysed cases the production quantity is almost the same for all versions. However, the loading times are much more important for the production process in case of discontinuous handling machines. The cause of this situation that the model contains 12 loading operations, and the total time of the loading is much more than the total time of the transport operations (at limited workplace area).

As we can see on Fig. 7.b, the reduction of the loading times do not cause noticeable changes for the conveyor, but significantly increases the production performance in the other two cases. The changing is 20% in the production quantity between 10s and 8s loading times, during 2 hours production.

The changing of the loading time also affects the other simulation parameters, Table 4 presents some data in case of 8 s loading times.

Table 4 – Simulation results of the different versions (8 s loading times)

COMPARISON PARAMETERS	Version A	Version B	Version C
Produced quantity [pcs]	56	53	47
Average waiting times of the stations [%]	3,2	6,2	15,5
Rise time [s]	583	644	693
Cycle time [s]	120	124	140

Based on Table 4 we can say that the reduction of the loading time also reduces the cycle time, and a limit value can be calculated where the cycle time reaches the minimum value and the transportation fits to the production time (limit values: 6,3s for manual handling and 7,7s for crane handling). Below the limit value the handling machine must wait at the loading points, above the limit the parts must wait on the buffers which increase the cycle time (Fig 8).

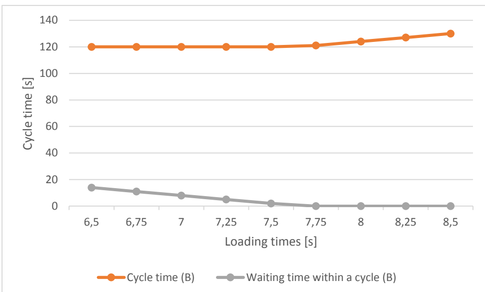
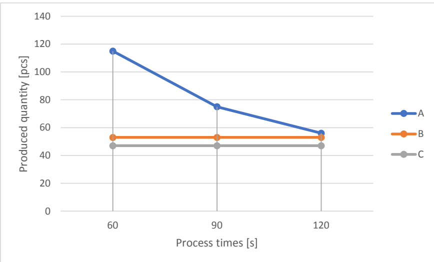


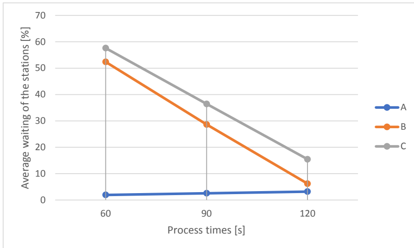
Figure 8 – Effects of the loading times to the cycle time
and the waiting time of the handling machine

5.5. Analysis of the modified production process

Another important parameter for material handling solutions, how it can fulfil the requirements of the changeable production process. Fig. 9.a presents the production quantities of the versions if the process time is changing. It can be seen, that discontinuous machines can not adapt the changing only the conveyor can react and result suitable quantities.



a) Effects to the production



b) Effects to the waiting times

Figure 9 – Effects of the changing of the process times to the versions

The handling solutions in Version B and C are not enough flexible to adapt the changing, their scheduling is determined and cannot be easily modified. In this case, the changing of the process appearing at the stations as waiting times (see Fig. 9.b).

Of course, we can increase the number of the discontinuous machines and it will result better handling process, however this solution is not so easy for cranes in this limited area. Much more usable possibility is the increasing of the number of the human workers, but it requires more complex routing to avoid the disturbances.

5.6. Conclusions of the simulation analysis

Summarising the results of the above detailed analysis of the workplace handling solutions, we can say that

- using of continuous handling machines for workplace handling is effective and flexible solution, but expensive and has continuous energy consumption and maintenance requirement,
- application of discontinuous handling equipment is simple, cheap and effective, but requires exact parameter setting for the optimal operation, which limits its flexibility,

- using of manual workforces is also simple and effective, the handling system can be flexible if the number of the workers is optimized, however in complex cases the route-planning can be hard task.

Another important observation is the importance of the loading times in small, limited areas, which determines the cycle times of the discontinuous handling solutions.

Of course, these consequences are general statements, the actual parameters of the workplace environment can modify the application characteristics of the individual handling solutions.

6. SUMMARY

People use many items for different purposes, most of them are manufactured in different workplaces, so their structure and operation parameters are very important to reach the suitable consumption parameters. There are many material handling solutions can be used in the production workplaces depending on the workplace specifications. The main objective of the research presented in this paper was to compare the different handling solutions of production workplaces. After the overview of the material handling model and the handling equipment selection procedure of production workplaces, a comparison analysis of the applicable handling solutions was introduced. The last chapter of the paper presented an example for the comparison analysis of a given workplace.

As a result of the analysis some statements were described, which can be considered during the planning process of production workplaces.

Of course, the results presented in this paper are only some small parts of the research related to the material handling equipment selection process, and the consequences are general statements, the actual parameters of the workplace environment can modify the application characteristics of the individual handling solutions.

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ПОРІВНЯЛЬНИЙ АНАЛІЗ РІШЕНЬ ПО ПЕРЕМІЩЕННЮ МАТЕРІАЛІВ НА ВИРОБНИЧИХ РОБОЧИХ МІСЦЯХ

Анотація. *Загальна мета дослідження — розробка моделі, яка допоможе вибрати найбільш підходяще вантажно-розвантажувальне устаткування для виробничих робочих місць. Тема статті стосується порівняння різних рішень по обробці. Щоб показати застосовність концепції, був наведений приклад. Основною метою вибору устаткування є пошук найкращого рішення для всіх видів вантажно-розвантажувальних робіт. У процесі вибору здійснюється пошук оптимального рішення по заданій цільовій функції з порівнянням параметрів вантажопідйомних пристроїв і вантажно-розвантажувальних відносин. Залежно від типів параметрів процедура вибору устаткування складається із трьох етапів: виключення невідповідних рішень, врахування обмежень і порівняння застосовних типів машин. У цій статті аналізується тільки третій етап, порівняння застосовних типів вантажно-*

розвантажувальних машин. Процедура порівняння в кожному випадку заснована на одному або декількох числових параметрах, найбільш важливими з яких є транспортні відстані (вертикальні, горизонтальні і т.п.), час роботи (транспортування, навантаження, очікування і т.п.), визначені межі (наприклад, час початку виробництва), параметри машини (продуктивність, використання і т.п.). Для реалізації процесу обробки була створена імітаційна модель у середовищі Technomatix Plant Simulation, яка містить різні елементи моделювання варіантів обробки, що підходять для прикладного програмного забезпечення: виробничі станції, об'єкти перевантаження, ділянки транспортних ліній, джерела й стоки (вхід і вихід), вантажно-розвантажувальні рішення (конвеєри, крани, персонал), буфери й склади і т.д. У ході дослідження як параметри порівняння використовувалися продуктивність виробництва, транспортні потужності й час очікування. Підводячи підсумок можна сказати, що використання машин безперервної дії для вантажно-розвантажувальних робіт на робочому місці є ефективним і гнучким рішенням, але дорогим і вимагає постійного енергоспоживання й технічного обслуговування, застосування переривчастого вантажно-розвантажувального устаткування просто, дешево й ефективно, але вимагає точного настроювання параметрів для оптимальної роботи, що обмежує його гнучкість, використання ручної праці також просто й ефективно, система вантажно-розвантажувальних робіт може бути гнучкою, якщо кількість робітників оптимізована, однак у складних випадках планування маршруту може бути складним завданням. У результаті аналізу були описані деякі положення, які можна враховувати при плануванні виробничих робочих місць.

Ключові слова: *робота на робочому місці; моделювання; вантажно-розванта- жувальне устаткування; порівняння.*