Advanced Logistic Systems, Vol. 8, No. 1 (2014), pp. 93-102.

APPLICATION OF DEVICE-PRESELECTION FOR DISCONTINUOUS UNIT HANDLING

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Abstract: Design methods, which are available in the literature, cannot give universal, generally applicable solution for materials handling systems, so development of a new design concept is required. The aim of my research is to develop a new method which can increase the effectiveness of the design process and gives a more applicable solution. The key element of the design concept is a device preselection step which was published earlier [1]. In this paper the applicability of the device preselection process are shown for unit handling machines with discontinuous operation.
Keywords: materials handling systems, integrated design, device-preselection, unit handling

1. Introduction

Design of a materials handling systems is not a simple task. There are many methods for the selection of the different equipment and to determine the details of the material flow tasks, but none of them can give a generally applicable, effective solution.

The most problematic point is the large deviation between the different devices and the material handling tasks. During my research, the aim is to develop a new method which can increase the effectiveness of the design process and offers a more applicable solution. The new process, which was published in the year 2013 [1], fits to the logic of the integrated design, supplemented it with an additional subtask called device preselection.

In this paper, I analyse the applicability of the preselection process for discontinuous materials handling machines in case of unit handling tasks. Beside the theoretical design process, I show a practical example based on some data from the literature [2, 3].

2. Design of materials handling systems

During the design of a materials handling system we are looking for serving equipment for a complex materials handling task and synchronizing their operation. The solution can be task-based or system-based approaching. Task-based approaching uses individual materials handling tasks during the design process, system-based approaching analyses the whole system and the relations of the system elements [4], and tries to find similarities with other systems.

The task-based approaching is much more published in the international literature, its important advantages are the using of real material flow parameters and better mathematic description.

Task-based approaching has four main subtasks (Figure 1.):

A. Design of the allocation of the materials handling objects
B. Selection and dimensioning of materials handling devices

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C. Selection of unit loads
D. Scheduling of the materials handling tasks

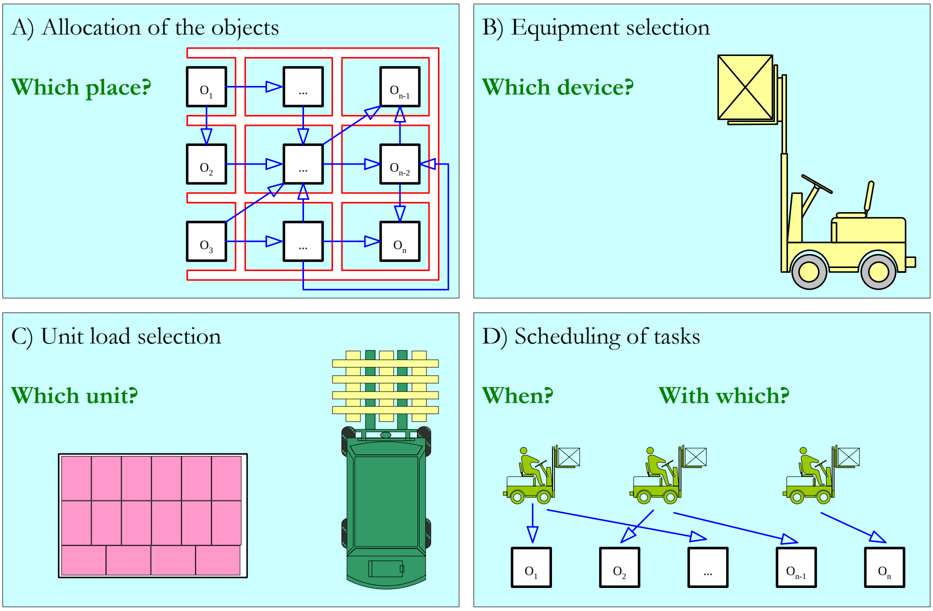

Figure 1. Subtasks of the design of materials handling systems

In the aspect of the solvability of the design tasks of materials handling processes, there are four different cases:

- only one subtask has to be solved (individually),
- traditional device selection methods,
- integrated design processes,
- integrated design processes with device preselection.

If the design subtasks can be solved individually, the design process will be easier because there are many proved specific method [1], but one problem is appearing: the designed system will be optimal only in the aspect of the given subtask.

The aim of traditional design methods to find a suitable serving device for the related technology objects and tasks, so the main task is the selection and dimensioning of the materials handling equipment, depending on the previously determined parameters of the other design tasks. Traditional equipment selection methods can be categorized based on Welgama and Gibson [5] as analytical methods, knowledge-based methods and hybrid methods.

If all of the subtasks have to be solved, then we have to use an integrated design process. In this case the subtasks can also be actualized individually, however the subtasks effect each other, so an iterative method is required. The iteration number is determined by the complexity of the materials handling task (it can be huge in complex cases).

As the result of the design procedure we got an equipment set and an allocation variety which are near the optimal serving solution.

One of the most important causes of the problems of integrated materials handling design that the selection and the dimensioning of the equipment are treated as one element [6]. This concept is acceptable in the aspect of the practice because they are coherent, but it requires that all of the design steps have to be actualized on all of the possible machines.

A possible solution for the above mentioned problem is the integrated design with device-preselection [1], which divides the device design subtask into two individual steps:

1. Preliminary determination of the equipment types (preselection)
2. Dimensioning of the given devices

Preselection of the equipment means a procedure [1] to determine the principally suitable materials handling machine types based on certain parameters of the tasks and the devices. The dimensioning phase is served for determining of the required performance and the specialisation of the selected equipment. For this purpose exact dimensioning methods or knowledge-based selection methods can be used [7, 8].

As a result of this concept the other three subtasks have to be actualised on the selected machines.

3. Device preselection

Obvious possibility is to use simpler knowledge-based selection methods for the preselection, however there is some problem. The principle of the knowledge-based selection procedures is the general solution search in which they combine the selection and the dimensioning. Because of this approaching these methods cannot be adapted into the preselection. Another specification of the knowledge-based methods is that they use a predefined algorithm with discrete steps for the design. It is also cannot be applied in the preselection, because the simplified comparison lets the using of an analytical process based on numerical parameter values.

During the selection process the optimal solution is searched along a given objective function with the comparison of parameters of the materials handling device and the required task. The aim of the preselection is to select the best materials handling equipment type using an analytical process, which requires numerical parameters.

Materials handling parameters can be [9]:

- exclusion-type parameters,
- limitation-type parameters,
- numerical parameters.

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 (for example: forklifts cannot be used for 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 at the different materials handling machines. Equipment can be qualified based on numerical parameters with the next formula [1]:

$$M_E = \frac{\sum_{i=1}^{n} e^{-\gamma_i \cdot \left|\frac{p_{Ei}-p_i}{p_{Ei}}\right|^{\delta_i}} \cdot \beta_i}{n} \qquad (1)$$

where

p_i – is the required value of task parameter i,
γ_i – is a coefficient to determine the analysis range of parameter i,
β_i – is the weight coefficient for defining the importance of parameter i,
δ_i – is a coefficient to determine the applicability range of parameter i,
n – is the number of the analysed parameters,
p_{Ei} – is the optimal value of the device parameter i.

Depend on the above mentioned process and the defined parameters, the device preselection procedure can be actualized by the algorithm shown on Figure 2. The most important element of this method is the determination of the different parameter types, their roles and their values in the design process.

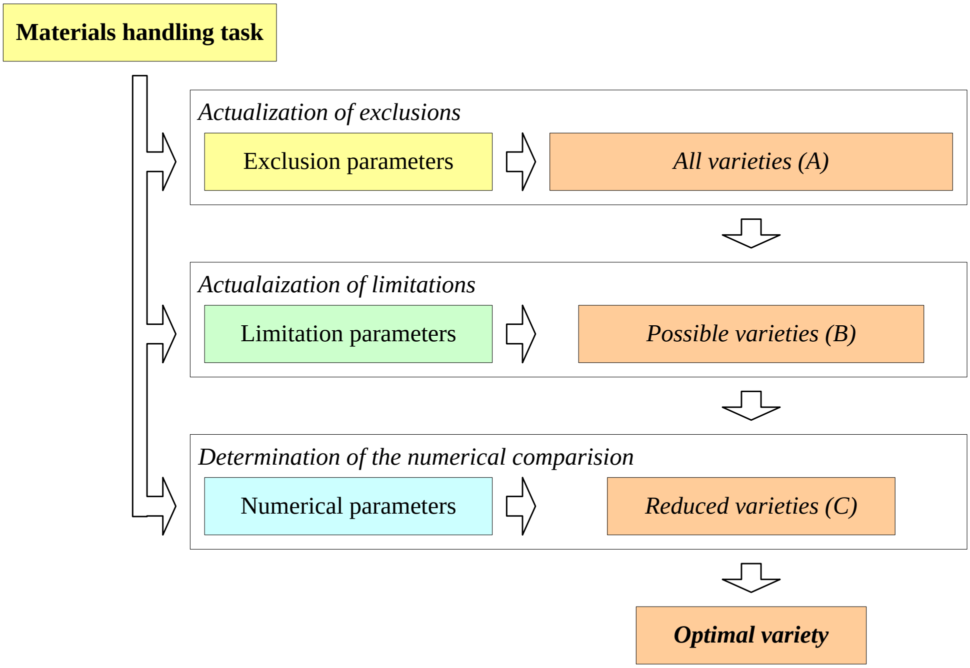

Figure 2. The algorithm of the device preselection [9]

4. Device-preselection for unit handling

Properties of the handled materials basically define the applicable equipment. During the materials handling processes all material can be handled, but only in solid state (liquids and gases have to be filled in a tank). In the aspect of the handling behaviours we can talk about units and bulk solids.

Units are those goods which can be transported, loaded and stored individually, their sizes, masses and other handling properties can be very different. Moving of these materials can be actualized individually or in unit loads. Bulk solids consist of different (in size and form), in generally homogeneous particles, which can be transported, loaded and stored in large masses without any kind of packaging [2].

The most applied unit handling devices can be seen on Figure 3. In the aspect of the preselection process there is a significant difference between continuous and discontinuous operation. Machines with discontinuous operation works only during the actual task and waits between the work phases. Continuous machines are always operating independently of the task, they transport goods between a source and a destination point.

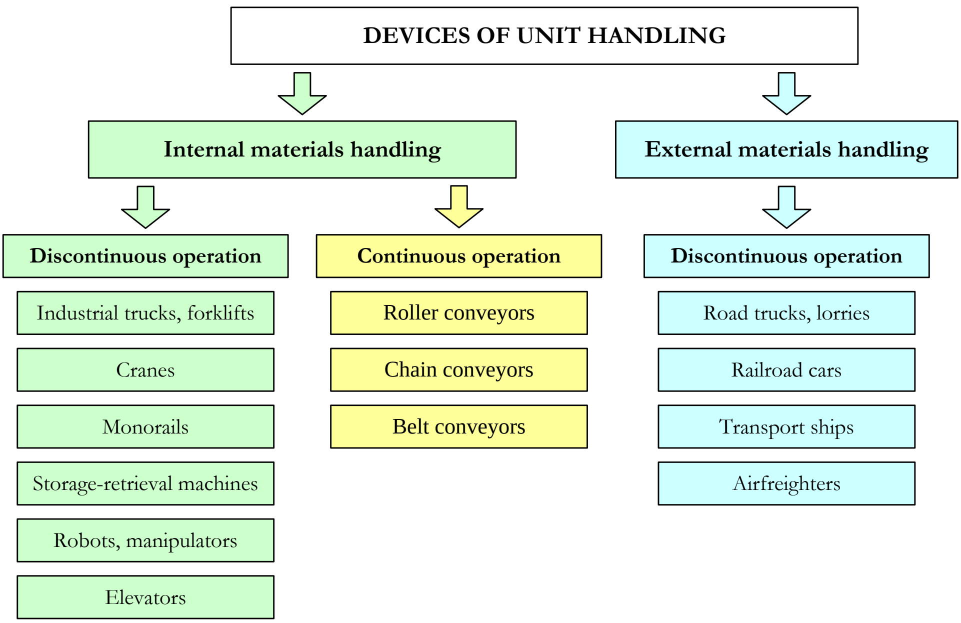

Figure 3. Types of unit handling equipment

In this paper I am dealing with only the discontinuous unit handling equipment, which transport or load given units between two objects in work cycles [6].

Specifications of the discontinuous unit handling for the preselection process:

- individual unit handling,
- loading times have important role,
- there is no direct relation among the devices,
- periodic serving cycles, etc.

Exclusion parameters of discontinuous unit handling machines can be grouped in four category (Table I.), which characteristically separate the different devices.

Table I.

Exclusion parameters of discontinuous unit handling machines

	Function	**Track line**	**Serving method**	**Goods handling**
Forklifts	L, ST	F, GT	AT+V	SG, CG, HG
Platform trucks	T, S	F, GT	AT	-
Travelling cranes	L, ST	LT, HT	HP+V	HG
Hoists	L, ST	HT	AT+V	HG
Jib cranes	L	RT	HP+V	HG
Monorails	T	HT	AT+V	HG
Robots	L	RT	CA	CG
Storage-retrieval machines	L	VP	AT+H	SG
Elevators	T	VT	AT	-

AT: along tracks, CA: complex area, CG: clutching, F: free movement, GT: ground track, H: vertical direction, HG: hanging, HP: vertical plane, HT: high track, L: loading, RT: rotating track, T: transport, S: storage, SG: supporting, ST: short transport, V: vertical direction, VP: vertical plane, VT: vertical track

The main role of the limitation-type parameters is to define the limit values of the numerical parameters (for example: γ coefficient), which can be different for every individual task. Taking the not numerical limitation-type parameters into account is not easy and in generally requires practical experience (for example: clutching of a unit with complex shape can be easily solved by hanging, but it exclude the application of some handling device).

Main limitation-type parameters of discontinuous unit handling:

- numerical:
  - size and mass of the units,
  - 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 objects,
  - track-line limitations (closed areas),
  - height limits,
  - turnover limits, etc.

Limitation-type parameters define the limit values of the numerical parameters of discontinuous unit handling (Table II.) and their values can be calculated by equation (1).

Table II.

Numerical parameters of discontinuous unit handling

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. Example for the device preselection for unit handling

To check the applicability of the device preselection process I made a simple test in case of discontinuous unit handling machines. Test parameters are the following:

- transportation and loading between two points (one source and one destination),
- discontinuous operation,
- simple transport line,
- using of one machine (if it is possible),
- distance between the objects is 100m,
- transport velocity is 50m/min,
- loading height is 6m,
- mass of the goods is 5000kg,
- transport intensity is 30 min/task.

The first step of the algorithm is the analysis of the exclusion-type parameters (based on Table I.), which contains the next aspects:

- as a complex (transport and loading) device is required platform trucks, jib cranes, robots, storage-retrieval machines and elevators are excluded,
- using monorails at short, simple line and small performance is not economical,
- after the excluding, only three device types are applicable: forklifts, hoists and traveling cranes.

As there are no limitation-type parameter among the given characterisations of this simple task, so the limit values of the numerical parameters was determined on practical experiences of literature data [2, 3]. During the examination only three parameters was taken into consideration (transport velocity, loading height and carrying capacity), their limit values and the coefficients of the calculation form (which determine the shape of the functions) can be seen in Table III.

Table III.
Numerical values of the parameters and the design coefficients [2, 3]

	Recommended limits from the literature		Design coefficients	
Forklifts	**min.**	**max.**	**γ**	**δ**
Transport velocity [m/min]	60	420	8	7
Loading height [m]	1,5	6,4	6	5
Carrying capacity [t]	0,6	6,3	7	7
Hoists	**min.**	**max.**	**γ**	**δ**
Transport velocity [m/min]	20	63	25	6
Loading height [m]	6	12	40	4
Carrying capacity [t]	0,25	12,5	5	9
Travelling cranes	**min.**	**max.**	**γ**	**δ**
Transport velocity [m/min]	50	125	50	6
Loading height [m]	8	32	20	7
Carrying capacity [t]	5	320	4	12

Figures 4-6. show the suitability values of the different devices at different transport velocities, loading heights and carrying capacities. If the suitability is near 1, the device is applicable for the given task in the aspect of the actual parameter.

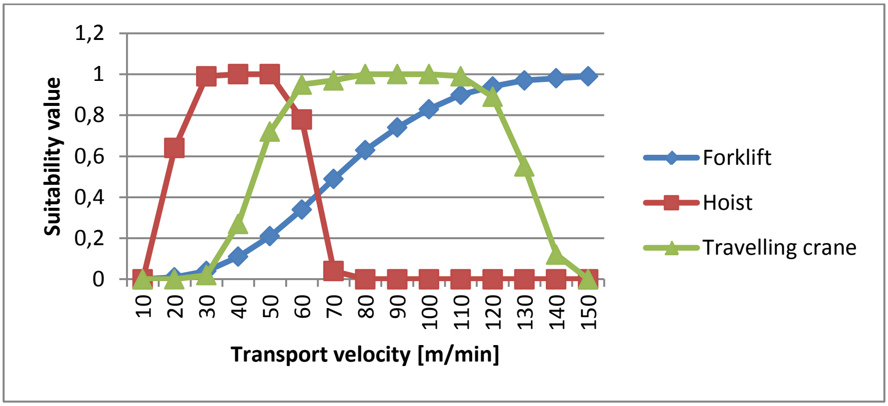

Figure 4. Suitability of the machines in the aspect of transport velocity

The values of M_E - defined in equation (1) -, taking all of the three parameters into account, can be seen in Table IV. at different parameter varieties (in this paper I have analysed only the effects of the velocity). As the values show, the optimal device for the example (Variant 2) is the hoist in the aspect of these three parameter. As the different variants differ only in the velocity (v), it can also be seen that above v=70 m/min the application of forklifts is the best.

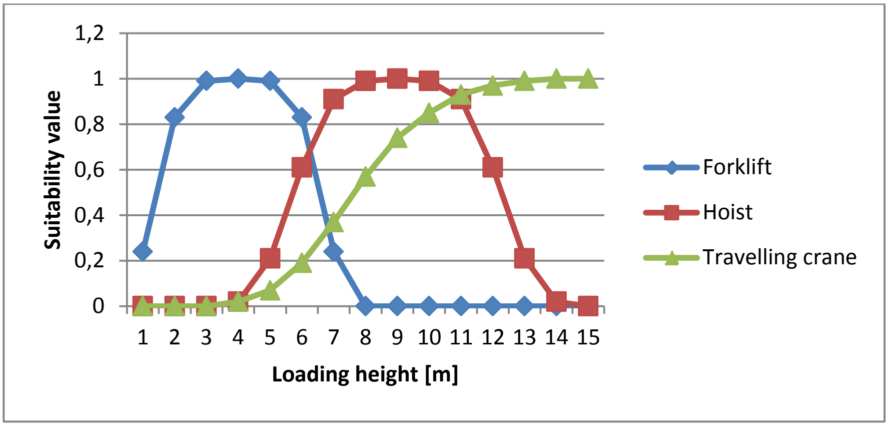

Figure 5. Suitability of the machines in the aspect of loading height

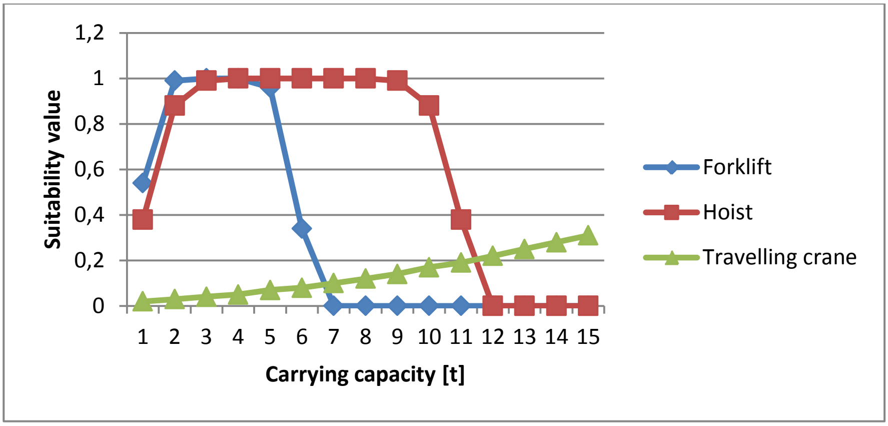

Figure 6. Suitability of the machines in the aspect of carrying capacity

Table IV.

Qualification values of the materials handling devices

	Forklift	**Hoist**	**Travelling crane**
Variant 1.	0,63	**0,87**	0,18
v=40 m/min, H=6 m, Q=5000 kg			
Variant 2. *(the example)*	0,67	**0,87**	0,33
v=50 m/min, H=6 m, Q=5000 kg			
Variant 3.	0,71	**0,8**	0,4
v=60 m/min, H=6 m, Q=5000 kg			
Variant 4.	**0,76**	0,55	0,41
v=70 m/min, H=6 m, Q=5000 kg			

The above mentioned results have only demonstrative role, because the examination was realized on three parameters. To get really usable results the research has to be widened to more parameters. Another possible development is to determine better functions to describe the applicability range of the individual materials handling machines.

6. Summary

Design methods, which are available in the literature, cannot give universal, generally applicable solution for materials handling systems, so the development of a new design concept was required.

During my researches I have divided the device design subtask of the integrated design scheme into two part: a preselection and a dimensioning process. With an effective device preselection and a simple dimensioning the effectiveness of the design process can be largely increased.

The focus of my research is on the device preselection, this paper showed the application for discontinuous unit handling machines. The results of the sketched examination is that the algorithm of the preselection is usable for the qualification of the devices (with three parameters), but general consequences cannot be stated.

The next steps of the research are taking more design parameters into account and deeper analysis of the applicability range of the materials handling machine types.

Acknowledgements

This research was partially carried out in the framework of the Center of Excellence of Mechatronics and Logistics at the University of Miskolc.

References

[1] Telek, P. (2013) *Equipment preselection for integrated design of materials handling systems.* Advanced Logistic Systems. Theory and Practice, Vol. 7(2) pp. 57-66. HU ISSN 1789-2198

[2] Felföldi, L. (ed.) (1975) *Materials handling handbook (in Hungarian).* Műszaki Könyvkiadó, Budapest

[3] Mihajlov, E. D.; Sztojanov, S. B.; Tolev, N. A. (1988) *Operation and maintenance of industrial trucks (in Hungarian).* Műszaki Könyvkiadó, Budapest

[4] Bányai, T. (2012) *Structured modelling of integrated material flow systems (in Hungarian).* GÉP, Vol. 63(4) pp. 83-86. ISSN 0016-8572

[5] Welgama, P. S.; Gibson, P. R. (1995) *A Hybrid Knowledge Based/Optimisation System for automated Selection of Materials Handling System*. Computers Ind. Engng., Vol. 28(2) pp. 205-217.

[6] Cselényi, J.; Illés, B. (ed.) (2006) *Design and control of material flow systems I. (in Hungarian).* Miskolci Egyetemi Kiadó, Miskolc, ISBN 9636616728

[7] Hosni, Y. A. (1989) *Inference engine for materials handling selection.* Computers Ind. Engng., Vol. 17 pp. 79-84.

[8] Fisher, E. L.; Farber; J. B.; Kay, M. G. (1988) *MATHES: an expert system for materials handling equipment selection.* Engng Costs Prod. Econ., Vol. 14 pp. 297-310.

[9] Telek, P. (2014) *Design properties of materials handling machines (in Hungarian).* MultiScience - XXVIII. microcad International Multidisciplinary Scientific Conference, University of Miskolc, 10-11 April, 2014. CD proceedings C1: Logistics section No. 10. ISBN 978-963-358-051-6