MODELLING OF MATERIAL FLOW SYSTEMS

PÉTER TELEK[1]

Abstract: Material flow systems are in generally very complex processes. During design, building and operation of complex systems there are many different problems. If these complex processes can be described in a simple model, the tasks will be clearer, better adaptable and easier solvable. As the material flow systems are very different, so using models is a very important aid to create uniform methods and solutions. This paper shows the details of the application possibilities of modelling in the material flow processes and systems. I give a short overview about the determination of the elements of the material flow processes, describe their relations and show an example for the application of modelling in the allocation design process of material handling objects.

Keywords: material flow, modelling, design methods, complex processes

1. Introduction

Material flow is a simple physical process in which materials, goods or living creatures are moving along a transport channel between two or more objects. In material flow processes the process elements have got direct relations, in material flow systems these relations are not unambiguous because of the possible varieties.

Industrial material flow systems can be very different depending on their application fields and operation environment. At the design of such processes, where the number of the applicable varieties is very high, the modelling is a very important aid to create uniform methods and solutions to make the tasks clearer, better adaptable and easier solvable.

2. Modelling of processes and systems

Building of models is one of the most ancient activity of humans and it is a basically important part of their thinking. In the model building process we make abstractions about the most important properties of a real or virtual system [1].

The aim of the modelling is to make a more simple process which is similar to the real one, to make the real model analysable [2]. All models are created to one special purpose, so different models can belong to one given process. Sometimes the analysis of a complex process can require more than one model which describe different parameters of one process. The structure of the models are different in the aspect of the applied rules and principles, at the industrial processes the mathematical and physical models are the most important.

Mathematical model of a real process means an abstract description which can be studied by mathematical methods, but it deals with only the basic relations and neglects those elements which have not got primary effects to the process [3].

[1] assistant professor, University of Miskolc
alttelek@uni-miskolc.hu
H-3515 Miskolc-Egyetemváros

The physical models contain also the physical principles and relations, and the effects of the environment beside the abstract mathematical description. Therefore the physical models are valid only at given operation conditions and limited environment.

One of the most important key factors of the modelling is the model building, in which the real process has to be described as a chain of simple, basic elements. Then leaving the negligible elements (in the aspect of the purpose of the analysis), the process has to be built again from the main elements in a more simple form.

The elements used for a given model are selected depending on the analysed process or system. The structure of a model is determined always by the main elements, their functions and their relations. Relations among the elements can be different (parallel, linear, loop, etc.).

The model building is not a linear process (Fig. 1.), during the building the applicability of the structure has to be controlled and the results can require the modification of the model structure. As the modifications have got effects to the original model, this is an iterative process. Model building has to contain the analysis of the validity and their limitations.

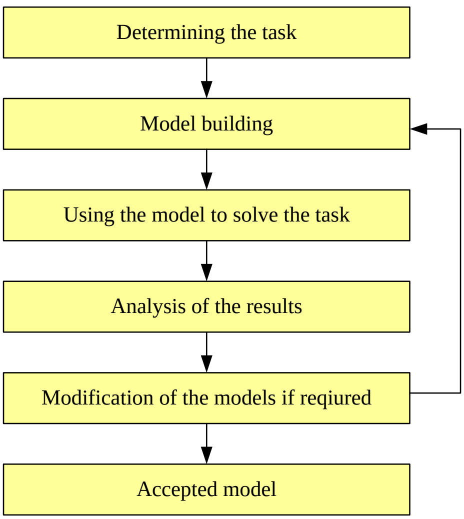

Figure 1. General model building process

To define a model for a given process we need some important model parameters (see Fig. 2.). By the help of objective functions we can determine the parameters of the real process, which can be examined by the model. Objective functions can be different parameters of the process (for example: operation cycle times, performances, costs, etc.). Descriptive equations define the mathematical relations among the model elements, the environment and others suited to physical or other rules. The operation conditions define the limits and restrictions of the process, the validity limitations determine the application fields of the model.

If the process is used to solve a given task, the model can contain a solution method and the varieties of the solutions. If the basic characterisations of the process are known, the examinations of the process parameters required by the objective functions are made using the model.

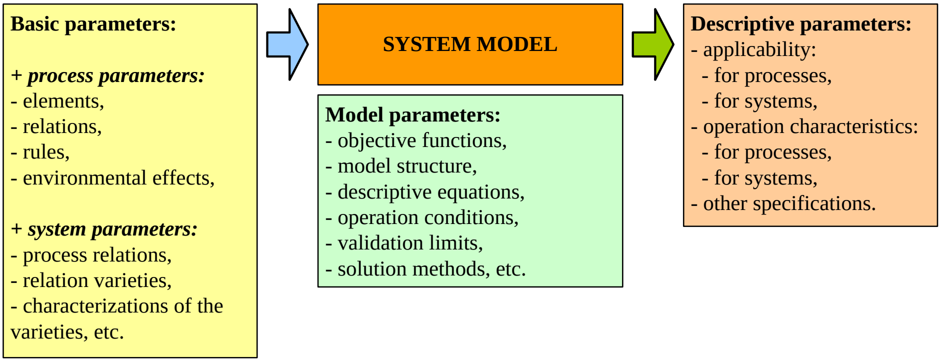

Figure 2. A general system model

The model of a system can be built in generally on their basic process model (or models) because the main elements are the same. Systems containing parallel processes can be modelled by the models of their processes. Structure of a general system model in generally more complex than an individual process model, but the elements and the relations are similar, differences appear in their parameters. Objective functions of system models are different from the process models, in many cases more than one objective function can be taken into account (mainly at parallel processes) and the mathematical formulas are suited to them. Operation conditions and validation limits can also be different for the parallel processes and the whole system. Beside the basic parameters of the used processes system parameters (relations of the processes, relation varieties, variable characterisations, etc.) are also required to describe the behaviour of the system and the determinant parameters have to be determined for the individual processes and for the whole system.

3. Modelling of the material flow

Main aim of the modelling of a material flow process is to build a model which can be used in design, control and optimisation tasks. There are three individual levels of the applicable models of materials handling systems:

- operation models of materials handling equipments,
- models of the basic processes of the material flow,
- models of complex materials handling processes.

At materials handling machines modelling is served for the examination of the dynamical behaviour, where problems of the operation can be uncovered. The models of the base processes of the material flow (loading, transporting, storing, packaging, etc.) are used for controlling of the realization and the operation, and can be very different. Modelling has the most important role at the analysis of complex material flow processes, which in generally contain more than one base processes. The larger the complexity of the processes the most complex model has to be built. Some process can not be treated without modelling. The material flow processes can be analysed using one model (at one objective function) which in generally mathematical, physical or structural models.

Structural models contain only the relations of the elements and are not suitable for detailed examinations, but they have important role in the analysis of the realization and the informing of the operators [4].

As the models of the materials handling processes are very different so their applicability and validity can be significantly limited. Different model has to be applied in generally for different operation characteristics (continuous, discontinuous), moving restrictions (free moving, moving along a line, etc.) and material characteristics (pieces, bulk solids, etc.) [5].

Basic parameters required by the model building process are suited to the characterisations of the given material flow process (Fig. 3.), where the most frequently used elements are

- objects,
- transport channels,
- material handling devices.

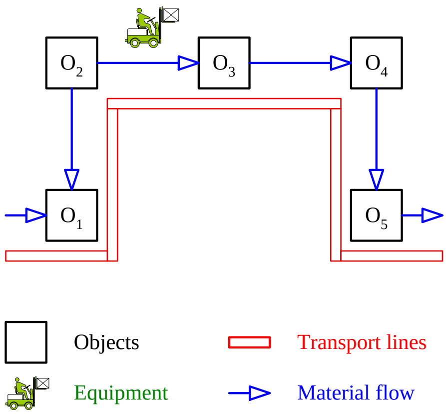

Figure 3. Example for a base material flow process

Relations among the elements of the process are determined by the material flow parameters, which can be given in different forms (for example: material flow matrices, relation matrices, intensity matrices, etc.). The rules taken into account in the material flow processes are in generally physical equations related to the moving of the goods (gravity, frictions, etc.). The effects of the environment appear as the parameters of transport lines or related external processes and objects.

As the base parameters, the parameters of the model are also suited to the characterisation of the material flow processes. Objective functions and relations for the analysis of the material flow processes are the followings [5]:

- times (operation times, cycle times, waiting times, etc.),
- costs (installation, operation, waste, etc.),
- performances (handling, etc.).

- capacity exploitages (transportation, loading, storing, etc.).

At material flow the process parameters limit only the operation fields, the details of the operation are defined by special limitations and restrictions. Limitations let change the system parameters within a given interval, restrictions give fix values to certain parameters of the process, so they reduce the number of the possible varieties [5]. Limitations and restrictions can be defined for any element of the process or any relation of them. Validation limits define those parameter intervals where the results of the theoretical analysis based on the model are fitted to the real process (for example: the model of a lined equipment is not suitable for a free moving device).

A significant part of the solution methods applied for material handling tasks is usable in generally, but another part of them is served for specific tasks and fitted to the design process. If the relations among the objects are linear (one object has only one input and one output material flow), then the tasks can be in generally easily solvable. In case of more than one material flow relation of the objects, the tasks can be solved by an optimisation method (for example: centre-search methods, etc.) [5].

Among the descriptive parameters, the applicability means the selection of the optimal solutions (for example: device type), the operation parameters define the general characterisations of the model. Individual characterisations (for example: allocation matrix in allocation design processes) contain the results of the analysis based on the model.

4. Modelling of material handling systems

Most of the materials handling tasks in generally can not be solved - depending on the complexity level - by a single process however by the help of a system. Design and operation of material flow systems means mainly the harmonization and maintaining of the continuous material flow of the different processes of the system [6].

In material flow systems the relations of the objects are changing in time because of the changing material flow or the number of the devices used for the individual tasks more than one and they are operated independently. In the aspect of modelling materials handling systems have three significantly different varieties:

- systems can be simplified to one process,
- systems containing not constant material flow,
- large systems containing numerous devices and independent tasks.

Material flow systems can be simplified to process models (in small systems), if the material flow is constant in time among the objects and the distribution of the devices is also not changing. In large systems further condition of the simplification is the parallel operation of the subprocesses.

If the material flow is changing in time, then there are two possibilities to describe the system model:

- using special objective functions where the effects of the changing parameter can be avoided (for example: using the length of the transport lines instead of the materials handling performance),
- using statistical methods (average values, limit values, etc) for the changing parameter, however it requires previous statistical analysis.

In case of changing material flow the models give only approximate results and reduce the validation fields.

In case of large systems containing numerous devices and independent tasks it is better to link the objects to certain subfields to define the model and the material flow parameters should be calculated by statistical methods and based on changing values. At these models the results are valid only for the given subfields.

In the aspect of the system objects and their relations there are primary differences between the internal and the linking model elements [6]. Internal model elements have relations only with other internal objects, linking elements are related to other material flow systems (Fig. 4.). Beyond the above mentioned facts, system objects can be located on different hierarchy level which determines the characterisations of their relations.

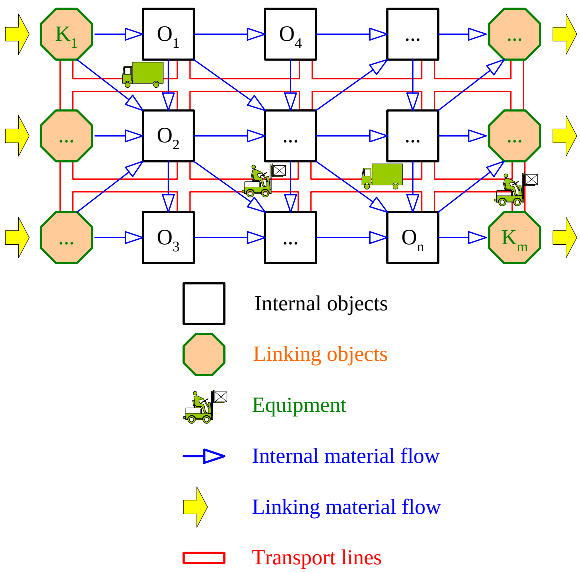

Figure 4. Example for a complex material flow system

Material flow system models (Fig. 5.) are not different from process models in their structure, the main differences are in the definition of their parameters. In these models, beside the basic process parameters, using of the system parameters are also required. The most important system parameters:

- relations of the individual processes in the system (independent, related, embedded),
- relation varieties (fix, changing, flexible, etc.),
- characterisations of the variables (deterministic, stochastic, etc.).

In the models of material flow systems special objective functions (for example: capacity exploitage, performance of the devices, substitution ability, etc.) are applicable which can not be used in generally in the individual processes. The structures of the system models are much more complex than the models belong to the processes and reflect the complexity of the relations of the individual processes.

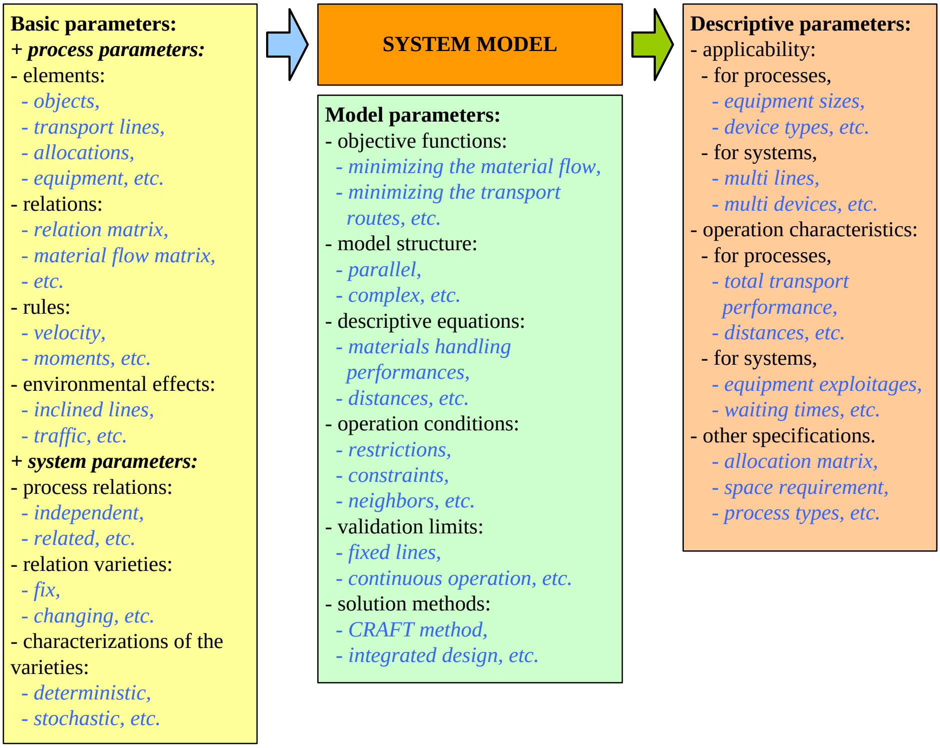

Figure 5. Example for the model of a complex material flow system (allocation design)

Operation conditions and validity limits have to be defined for both of the single processes and the whole system. In certain cases these conditions and limits can be the same, but in other cases can be very different.

Descriptive parameters have to be calculated for both of the processes and the system in the most of the cases. Among them, the applicability means mainly the selection of the optimal devices (solutions) in the aspect of the whole system, but it covers also the equipments of the individual processes.

Some of the operation parameters are served only for the description of the system (waiting times, exploitages, blocks, etc.). Among the individual parameters there are some significant one which suitable for determining the roles of the subprocesses in the model in the aspect of applicability.

5. Summary

As the material flow processes are in generally very complex so the design, building and operation of them contain many important problems. One of the suitable methods to reduce the complexity is the modelling which can help us to make typical, uniform groups of the processes. This paper summarized those factors which have significant effects to the modelling of the material flow processes and systems and showed the general structures of the applicable model types. By the help of the modelling the material handling tasks and design processes can be realized easier. In the next phase of this research I would like to go into details of some special material flow model (for example: industrial material handling systems, etc.).

Acknowledgements

This research was carried out as part of the TAMOP-4.2.1.B-10/2/KONV-2010-0001 project with support by the European Union, co-financed by the European Social Fund.

References

[1] Jávor, A.; Benkő, T.: Diszkrét rendszerek szimulációja, Műszaki Könyvkiadó, Budapest 1979. ISBN 963 10 2518 7
[2] Pogány, Cs.: Bevezetés a gazdasági rendszermodellezésbe, Számítástechnikai Oktató Központ, Budapest 1973.
[3] Buszlenko, N. P.: Bonyolult rendszerek szimulációja. Műszaki Könyvkiadó, Budapest 1972.
[4] Felföldi, L.: Anyagmozgatási folyamatok tervezése. Műszaki Könyvkiadó, Budapest 1969.
[5] Cselényi, J.; Illés, B. (edit.): Anyagáramlási rendszerek tervezése és irányítása I., ISBN 9636616728, Miskolc, 2006.
[6] Telek, P.: Anyagáramlási rendszerek változatai GÉP LXIII. évfolyam 2012/4. ISSN 0016-8572 pp. 23-26