SIMULATION OF MULTI-LEVEL ORDER-PICKING SYSTEMS WITHIN ROUGH PLANNING FOR DECISION MAKING

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KEYWORDS

multi-level order-picking systems, rough planning, simulation modules, decision making, key figures for order-picking systems, logistics, material flow

ABSTRACT

Rough planning of multi-level order-picking systems is a very difficult job because you have to consider a great number of versions. The planner has to decide on the basis of his experience, which systems will perform services best. In the early stage of development he cannot supply evidence that the systems he has chosen are better than others. Simulation can be a great means to ensure the decision of a planner by considering variability and changes in picking orders and assortments. This paper wants to point out how a planning tool can assist a planner so that he can do his job in a much safer way. For this, it is shown, which data is needed and what preparations have to be done for simulation. Then, it is shown, which standard elements are needed for automation of the simulation of the multi-level order-picking system. Furthermore, we want to point out what results you can achieve by simulation for the purpose of rough planning and how to validate them for decision making.

SIMULATION IN PLANNING OF ORDER-PICKING SYSTEMS

The order-picking is a section of logistics. From a total quantity of items (the assortment) subsets are assorted order-oriented.
Order-picking is considered as one of the most important subsections of logistics, because it is the most staff-intensive section (Alicke 2001).
The requirements of order-picking systems are changing, thus, dimensioning and design become increasingly more difficult.

Usually planning is based on average inventory data and dynamic data. For dimensioning, these values are projected linearly. This kind of planning has already reached its borders and cannot approximately satisfy the actually existing requirements of order-picking systems (Lüning 2005).

The simulation offers the possibility to use a larger database for the identification and dimensioning of order-picking systems.
Despite the progress of simulation technology, it is selectively used within the planning process.
Today the main fields of application are there, where the technical system is too complex for a conventional design or there, where the client would like to assure the results of planning.
Therefore, the system is modelled and simulated at the end of the detailed planning, so that the capacity can be validated (Haller 1997).
The usage of material flow simulation in earlier stages of planning – for comparing alternative concepts and for avoiding planning faults – is carried out rarely (Günthner 1997).

Within the AiF-research project ("Arbeitsgemeinschaft industrieller Forschungsvereinigungen", in engl. consortium of industrial research associations) No. 14601 by order of the Bundesvereinigung Logistik (BVL) e.V. (in engl. federal association of logistics) we are working at the Institute for Materials Handling, Material Flow and Logistics of the Technische Universität München in collaboration with the Fraunhofer IML of Dortmund with the aim to implement a simulation aided planning tool which can be used for planning multi-level order-picking systems within the process of rough planning.

ADVANTAGES OF SIMULATION IN ROUGH PLANNING

Using simulation for planning of order-picking systems in the early stage brings along the following three important advantages:

- Planning is based on a substantially more exact/broader database
- interactions between the individual ranges of an order-picking system are considered
- detailed investigation of several versions

The simulation offers the possibility of illustrating the system load by many individual values instead of one average value. The advantage is that the requirements of an order-picking system can be considered more precisely. Thus changes in the system load can be

Proceedings 21st European Conference on Modelling and Simulation
Ivan Zelinka, Zuzana Oplatková, Alessandra Orsoni ©ECMS 2007
ISBN 978-0-9553018-2-7 / ISBN 978-0-9553018-3-4 (CD)

considered over hours, days, weeks or years, as well as changes in the article and order structure.

Most order-picking systems consist of different ranges (techniques), so that they can be adapted better to the requirements of the articles and orders (Gudehus 2000). In one range only specific articles or order types are picked. That has the advantage that material flow, information and organisation system can be adapted exactly to the requirements of the partial assortment or order types.
The individual ranges are connected. Interactions, which can hinder the total output of an order-picking system, can be recognised by the application of the simulation. Thus, they can be considered during the system choice (Günthner 1997).
The planning tool and the standard modules can help to examine many versions in detail. Thus the risk, that a very good version is already excluded in the system identification phase, can be minimised, as the planner has considered it as inappropriate due to his experience.

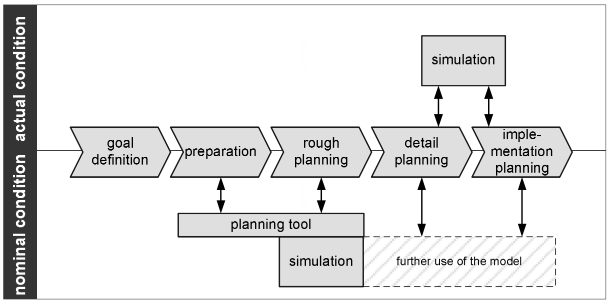

Figure 1: Usage of simulation environments in planning processes

NECESSITY OF STANDARDISATION AND AUTOMATION

Providing suitable simulation models for a multiplicity of versions is very complex. This is the reason, why simulation is usually first used in stages of detailed planning.
In order to be able to use the simulation in an earlier stage of planning effectively, it is imperative to have standard elements. By means thereof, it is possible to reproduce simulation versions with one detail level, which is sufficient for the rough planning.
The planning tool supports the planner while editing the input data. Further, it produces a standard system load for the simulation. With the help of seven standard modules, the planner can model the order-picking system with the planning tool. The planning tool generates the simulation model independently. Thus, the planner does not need detailed knowledge about simulation.
The planning tool is not bound to one specific simulation software. Only the appropriate standard modules have be converted in the simulation software. Furthermore it is necessary to have an interface between planning tool and simulation which is given by a relational database as you can see in the next section.

ARCHITECTURE OF THE PLANNING LOOP

The architecture of the planning loop is structured in three layers as shown in figure 2.

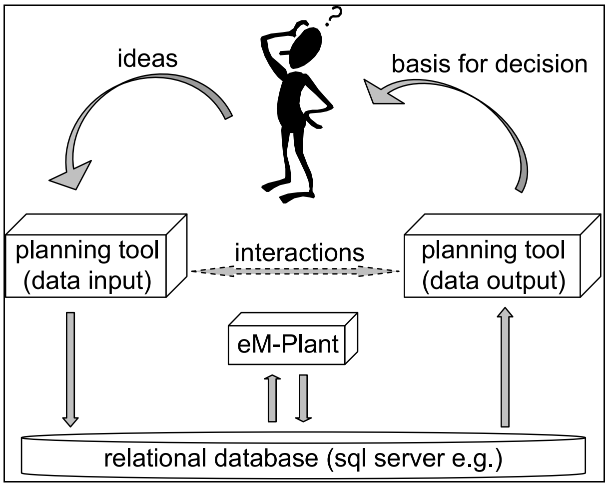

Figure 2: Planning loop

Within the top layer, the planner has ideas to solve his planning task and wants to know how good they are. Ideas embrace suitable solutions for structural and process organisations, which are possible solutions for the planning problem. In the middle layer a planning tool has to prepare the data needed, a simulation software has to determine values for every suitable solution and last but not least a planning tool has to determine key figures on basis of the simulation values. To handle all these data between the various steps, a relational database is used in the bottom layer.

WORKFLOW OF PLANNING

Planning begins with ideas on basis of the article structure data and depends on the planning task. Planning tasks can be redesigns or rationalisation planning. The planner has to analyse the data and find some versions (models) which could fit. The combinations of structural and process organisation of order-picking systems are called in the following context ‘models’.

According to the VDI guideline (“Verband deutscher Ingenieure” in engl. Association of German Engineers) 3633 the procedure of simulation is structured in the steps definition of aims, system analysis, data collection, modelling, verification, validation, experiments and the interpretation of the achievements as shown in figure 3.

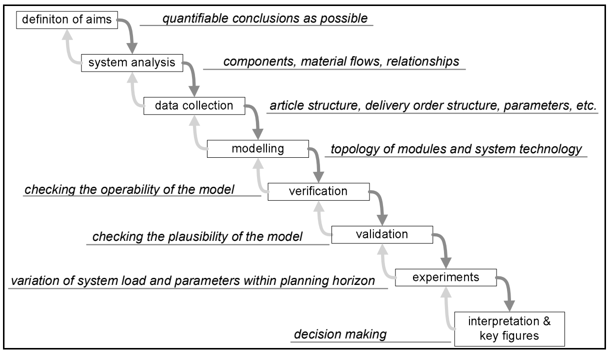

Figure 3: Model of cascade

In the first and very important step you have to define quantifiable aims to assess the achievement of objectives after simulation. For our specific field of application the target values are all the same and are defined once for all modules. These are especially time slices of picking. The planner does not have to do this step and can start with step two, the system analysis. As mentioned at the beginning of this section he has to find versions on basis of the article and delivery order structure.
For comparison of the models by simulation in the next step the planner has to input data which describes the system load. This can be performed by our planning tool. Then he has to model his versions as models in the planning tool. That means the planner has to choose the modules and their relationships of material flows.
Because of the standardisation of the simulation elements the steps of verification and validation can be abbreviated.
In the next step, the planner has to define the experiments. Depending on the planning task the planner has to decide how long he chooses the planning horizon. This could be a year, normally three till five years, but also longer periods are possible. Before experiments can start, the input data has to be prepared automatically by the planning tool. Preparation covers besides a lot of data transformations also the forecasting of the article and delivery order structure data during the planning horizon.
In the last step of the model of cascade interpretation of the simulation values have to be made by building key figures and drawing them in diagrams.
The next subsections are going to show you some details about the important steps of working with our planning tool and an example of simulation module.

Input of data and modelling of versions

Constituents of the input data are the article and delivery order structure data of the past (normally from the whole last year) and their forecast. The planning tool imports the data from any relational database and analyses them about distribution functions. Usually you cannot use the original data because attributes are missing for some data sets. So the identification of distribution functions is important to close these missing attributes. And, of course, you need them to generate articles and delivery orders for the future. Functions have to be found for the access frequency, volume and weight of articles and for the number of order items, order distributions within the day and quantity within an order item. The planning tool draws the distribution functions in a diagram as shown in figure 4 and the planner can decide if he wants to use the original functions or if he wants to use standard distribution functions like exponential, normal or equal distribution functions.

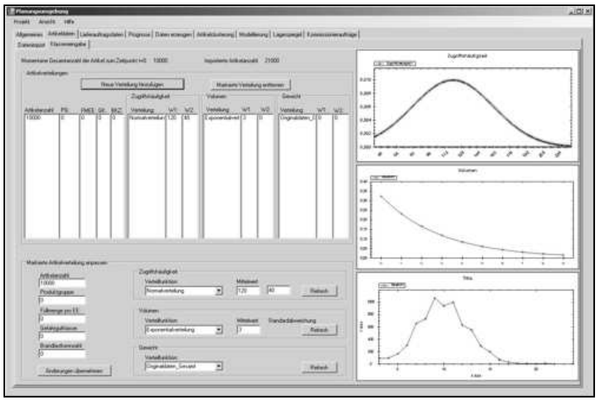
Figure 4: Planning tool for data preparation

If there are missing parts in the original data, the planner can also form groups and use different standard distributions for every group.
Inclusion of future for decision making implies that the planner inputs some forecasting. Figure 5 shows an example of changes in the delivery orders with three forecasts.

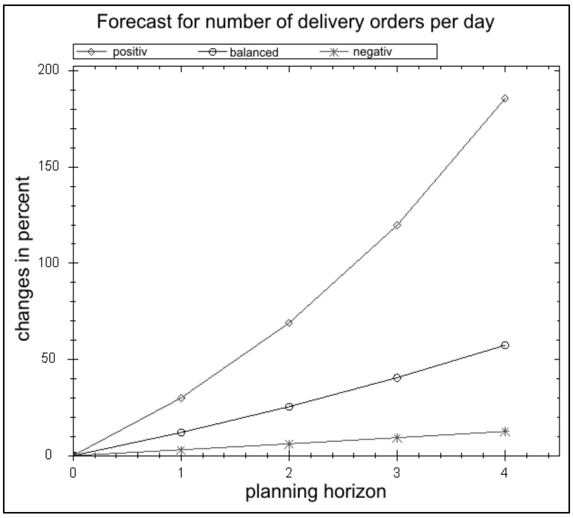

Figure 5: Forecast for number of delivery orders

The top line shows the positive forecast with 30 percent every year and occurrence probability of 35 percent. The balanced one is mapped with 12 percent rise and 40 percent occurrence probability and the negative one with 3 percent rise and 25 percent occurrence probability. Each forecast can contain changes in every distribution function as aforementioned.
According to these inputs the planning tool can start to generate the assortment and delivery orders for the complete planning horizon. Delivery orders are

generated by day, because we want to produce key figures for days with maximum and average system load. Every day symbolizes one test run. So, e.g., for three years of planning horizon, three various forecasts, two days for every year and prognosis there will be generated at least 3·3·2+1 (plus one because of the start status) test runs. For a high confidence level you should generate even more test runs for every day.
After Generating the planner draws the models consisting of modules (various system technologies) and their topology (material flow) in the planning tool and groups the articles to classes according to their attributes. Every module gets at least one group of articles or more. On basis of the articles in a module the module has to be dimensioned.
If all the steps below have been performed, the planning tool can automatically prepare the data for simulation.

Preparation of data

Before simulation can start, there have to be performed some more automatic steps. To get a bin status report for every article a bin location has to be generated according to its access frequency.
Also there have to be generated picking orders on basis of the delivery orders according to the topology of the model of a multi-level order-picking system.
After the picking orders are completed, the planning tool can generate series according to a series value, e.g., four. This means that the commissioner picks four picking orders concurrently.
Last but not least, the series have to be sequence planned. With all of this steps simulation can start.

Simulation

To reduce the effort in simulation, this step should run automatically as far as possible. We build some standard simulation modules which cover the majority of cases of single picking-order systems. These are module I as conventional picking (hand operated picking from ground-level compartment rack, pallets rack, live storage rack), module II as zone-picking, module III as automatical small-parts or pallets warehouse with terminals, module IV as reverse picking, module V as automatical small-parts or pallets warehouse with manual rack feeder, module VI as manual sorter, and module VII as automatical sorter.

Building these standard modules was carried out by cutting clear the smallest unit, e.g., one zone in the zone-picking module, to have the ability to build any dimension of a picking-order system by variables and putting together the units. An example for cutting free of a zone in the module II (zone picking) is shown in figure 6.

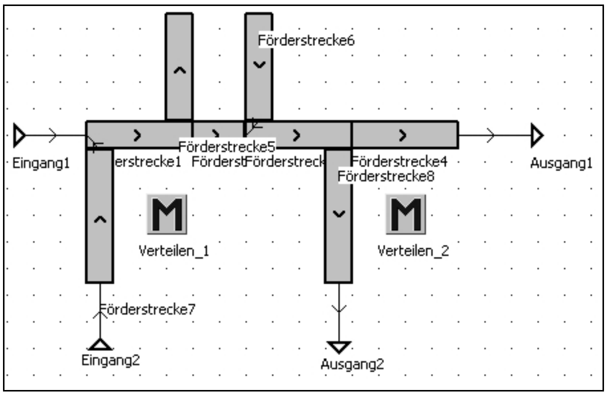

Figure 6: Cutting clear of elements within eM-Plant

Corresponding to the parameters the instance of a module can be build up by linking the smallest units. E.g. the number of zones is given for the module of zone picking, figure 6 can be linked according to this number.
After the instances of modules are built up, they have to be linked according to the relationships, the planner has inserted in the stage of modelling. As shown in figure 7, a multi-level order-picking system can be mapped in the planning tool as model and build up in the simulation environment.

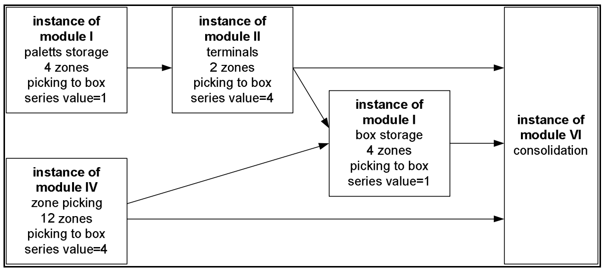

Figure 7: multi-level order-picking system model

After building up the model in the simulation environment, the system load has to be retrieved from the database. Communication between the simulation environment and the database should only happen at the start up and at the end because of the performance. So there has to be retrieved a big table with all of the data of picking-orders. A generator transforms the information of the table to movable elements which map picking boxes. During the simulation time slices of the orders are calculated.

Example of a simulation module

To show how an instance of an module looks like after building it up, an example of an instance of module II, the zone picking module, is given in figure 8.

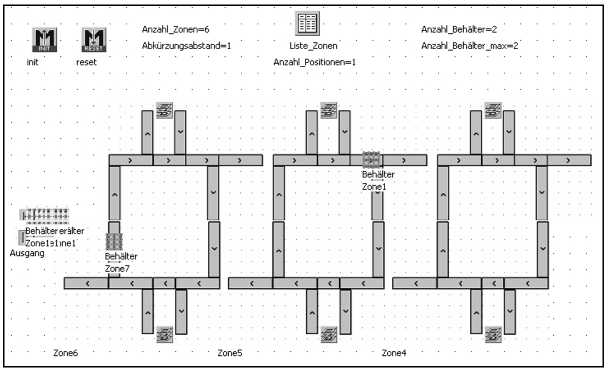

Figure 8: Zone-picking simulation module in eM-Plant

Building key figures for decision making

The values (time slices and allocations) from the simulation are stored in the database. Together with further inputs of the planner, they represent the basis of the evaluation. The evaluation consists of a monetary evaluation, of a performance evaluation and of a qualitative evaluation.

Monetary evaluation

The monetary evaluation consists of the calculation of the net present value and cost characteristic curves (cost keys). The application of the net present value method guarantees that the costs are evaluated in a temporal connection. Thus, it is possible to evaluate the changes (forecasts) monetarily.

The definition of occurrence probabilities allows calculating an expected net present value (Münster 2004).

Due to the planning environment the planner can display different cost characteristic curves. Figure 9 shows the costs per pick of the different changes of a version (model).

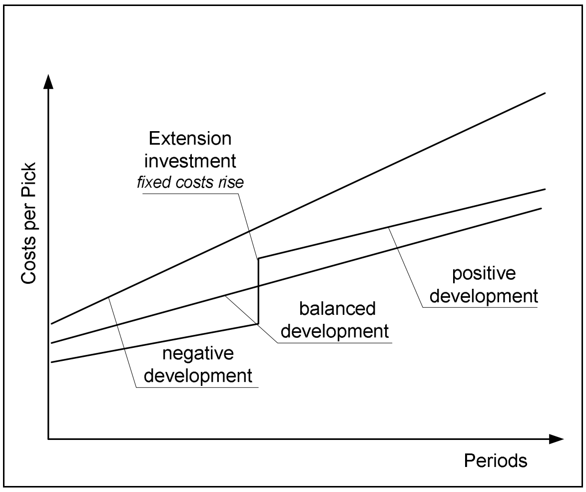

Figure 9: Costs per pick of different changes of a version.

Performance evaluation

In order to evaluate the performance of the versions better, performance characteristic numbers are calculated.

The productive time of an order picker is the picking time. The transit time, basis time, and the death time are necessary for the procedure of the order picking, but these time slices should be as short as possible, compared to the picking time. For the comparison of versions, the tool calculates the individual times and plots it. So the planner can compare the versions simply.

In order to evaluate the time slices of individual ranges of the modelled heterogeneous order-picking system, the planner can use filters. Figure 10 illustrates the computation of key figures.

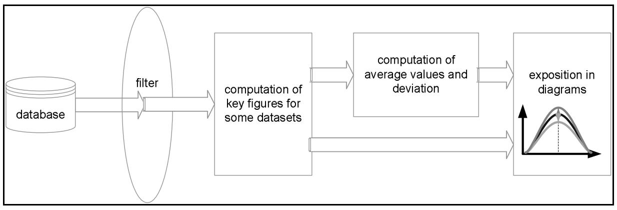

Figure 10: Computation of key figures

Qualitative evaluation

Not all important factors for the rough planning of heterogeneous order-picking systems, are illustrated in the simulation. These factors include questions of ergonomics, flexibility, or changeability of an order-picking system.

For the consideration of these factors, the planning tool contains a function for the execution of a cost benefit analysis. Here, the planner is supported by the planning environment, so that the plausibility of the inputs is guaranteed.

OUTLOOK

Until now, we have implemented the planning tool for input data preparation and computation of the key figures and four standard modules for simulation. So we have started with the first test runs of the whole planning loop. The next step will be the derivation of rules of configuration for heterogeneous multi-level order-picking systems. Therefore we investigate some existing systems of companies representative of small and medium-sized businesses. Furthermore, we investigate some special scenarios in the forecasts of these businesses. For demonstration and for comparison with reality we go along with a company near munich. The research work for the AiF-Project will be finished in the 3rd quarter of 2007. We want to compare the achievements of simulation with them of analytical methods. Therefore we develop at the Institute for Material Handlings, Material Flow and Logistics analytical methods for evaluation of order-picking systems in another research project in order by the Deutsche Forschungsgemeinschaft (DFG, in engl. German Research Association). By using a similar system load the achievements can appropriately be compared and validated.

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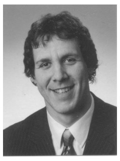

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