Simulation-aided conceptioning and planning of order-picking systems

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Development of a simulation-aided planning environment for the dimensioning and evaluation of multi-level order-picking systems and a heterogenous technical design under consideration of the effects which changed sales, order and assortment data have on the planning results.

Abstract

During recent years the logistic aspect of order-picking has become even more complex. While some 20 years ago a logistic planner had to consider and to evaluate approximately five system-variants, the variety of technical solutions has almost increased explosively in the last few years furthermore, current solutions show a more complex process behaviour and the interrelations between the different parts of a heterogeneous structured overall system are much more dynamical. Since this complexity and dynamic will continue to grow, the potentials of the current planning processes, which mainly rely on static calculations, will soon be exhausted. Considering this background, Fraunhofer IML in cooperation with the Department for Materials Handling Material Flow Logistics of the Technische Universität München developed a simulation-aided planning environment to dimension and evaluate heterogeneous multi-level order-picking systems already during the conceptioning phase. In the scope of this joint research project a prototype of a simulation-aided planning environment for picking systems could be developed, which allows for the evaluation of the ever more complex hetero-geneous picking systems at acceptable costs already during the rough planning under consideration of their dynamical behavior and to generate the required data and key values. The solution was based on a modeling paradigm as well as on the definition of standardized elements for the design of heterogeneous picking systems and their representation in a generatable simulation model.

1 Introduction

Scientists of the *Fraunhofer-Institut für Materialfluss und Logistik (IML)* in Dortmund and the *Lehrstuhl für Fördertechnik Materialfluss Logistik (fml)* of the Technische Universität München have developed a simulation-aided planning environment whichallows for the evaluation of the roughly planned variants of order-picking systems and the dimensioning of the required performance.

The order-picking process, i.e. the retrieval, sorting and provision of partial consignments (according to the customer order) out of a total quantity of articles (the article range) is an important aspect of in-house logistics. Because of the labour-intensive, often personnel-intensive and thus costly processes they offer a lot of potential for optimization.

The atomization of consignments in line with an increased delivery frequency and growing customer requirements, for example regarding order leadtimes, call for a flexibility which has to be planned prior to the physical realisation of a system. The termination or signing of delivery agreements, changes of the article range or a shift from wholesale trading to direct delivery of the final customer (e.g. pharmaceuticals) can drastically change the picking process.

This project aimed at finding a comprehensive solution for the selection and combination of suitable processes and working equipment in order to optimize the overall system by means of given article and order data. In fact, technical literature describes various single function modules within an order-picking system. However, the known selection and evaluation tools do not result in a cost-effective and efficient system with different picking zones working with different technologies and, if required even different order leadtimes.

To find the optimal system the following aspects have to be taken into consideration: Based on their performance-related characteristics (retrieval frequency, volumes to be provided, distribution of retrieved quantities onto packaging units) the articles to be picked have to be allocated to definite storage and picking areas. Furthermore, suitable rules have to be determined to control the order release and to roughly plan the sequence. (Target) order leadtimes have to be determined, the waiting times, which are caused by the synchronisation of order runs, have to be quantified and their effects on the overall system performance have to be identified. In addition to this, the supplies, retrieval quantities and times have to be coordinated and variants for the order control and allocation have to be evaluated.

Due to the resulting complexity the intuitively found picking systems can be submitted only to rough suitability tests. Detailed conclusions about the performance of a system can only be made after a simulation. But the project costs would then be unjustifiable, above all for SMEs. In the scope of this project as many different picking systems were modelled as were necessary to provide the maximum level of system variants used by the SMEs and to achieve a direct benefit for the companies. On the other hand, different system variants could be tested and evaluated at low expenditure like in a business game.

2 Common order-picking systems and their components

At the time of the research report the data included 42 companies with a total of 90 elementary components which were systematised according to their structure and characteristics. The topological study showed a trend towards simple structured systems. 98% of the picking systems consisted of not more than four components and half of all picking systems of not more than two components (except special storage equipment like bulk goods warehouses). In one out of two order-picking systems the components were arranged parallely to each other and 60% of the systems were single-level systems. 21% of the systems were designed for a two-level order-picking. Furthermore, it was studied how the articles were distributed to the different components. For 90% of the systems the components were designed according to the three criteria access frequency, article volume, and product group. With a share of 64% the majority of the systems were used for picking with a statical provision while 36% used a dynamical provision process. Based on these findings the single components, as they occur in heterogenously structured order-picking systems, were saved in the system in the form of modelling elements (also combined, if required).

3 Comparison of rough planning vs. detailed planning

According to the task of this project to support the planner during the rough planning the different planning and design aspects of an order-picking system were weighted with regard to their relevance for the rough and detailed planning. It soon became clear, however, that only few aspects could clearly be assigned to the detailed planning and that ignoring them may lead to wrong conclusions during the system comparison. To balance the high complexity on the one hand and the necessary detailing level on the other hand the following two strategies were integrated into the planning environment: Standard control and routing strategies were used which lead to satisfying results for most standard systems and allow for the quick and exact rough planning of variants for a system comparison without challenging each parameter in detail. At the same time, special systems can be represented and planned by flexible parameters. Thus, it is possible to represent, for example, the equipment of a picking station with a pick-by-light technology by increasing the cost rate for each storage bin and by adjusting the preset values for the picking process time.

4 Selection of the simulation environment

The simulation is an integrative planning method and core component within a virtual value-added process. Because of its interdisciplinarity, which is demonstrated by product characteristics like 3D visualisation, hardware-in-the-loop concepts, distributed simulation, or mathematical optimization, it plays a special role. It also includes many components that facilitate the realisation of a digital factory, i.e. that can dynamically simulate each process step within a company's activities and their various interdepencies. Because of the large variety and high complexity of the processes to be studied the simulation is a key technology for the solution of this task. The suitable simulation tools for the rough planning of order-picking systems were selected according to the criteria interfaces and upgradeability, modelling and structuring, runtime behaviour but also economical aspects like the evaluation of marketable tools. Further criteria were the price and support offered by the supplier. As a result simulation and simulation development tools seemd to be the most adequate for the task at hand. Based on technical criteria and the detailed know-how of *Fraunhofer IML* finally the simulation tool *Enterprise Dynamics* by *Incontrol* was chosen for this project.

5 Simulation-aided rough planning

The planner should be able to virtually realise his ideas about a certain planning task and to compare different variants, i.e. to use the advantages of a simulation without being a simulation expert himself. For this purpose, the planner is supported by a Windows application tool which prepares the data for the simulation. The system learns about the defined variants of the order-picking systems via a modelling environment with several parameterisable standard components. During the simulation the time-frames for basic, travel, gripping and idle times are determined including start and end times. These time-frames are important for the order-picking process. After the simulation experiment these data are available and can be processed in the Windows application tool into key figures. By varying the input data the interactions with the output data can be shown so that, for example, the benchmarking of two order-picking systems shows different input data for each system. The generated key figures of the different variants are weighted and used to make and support a decision.

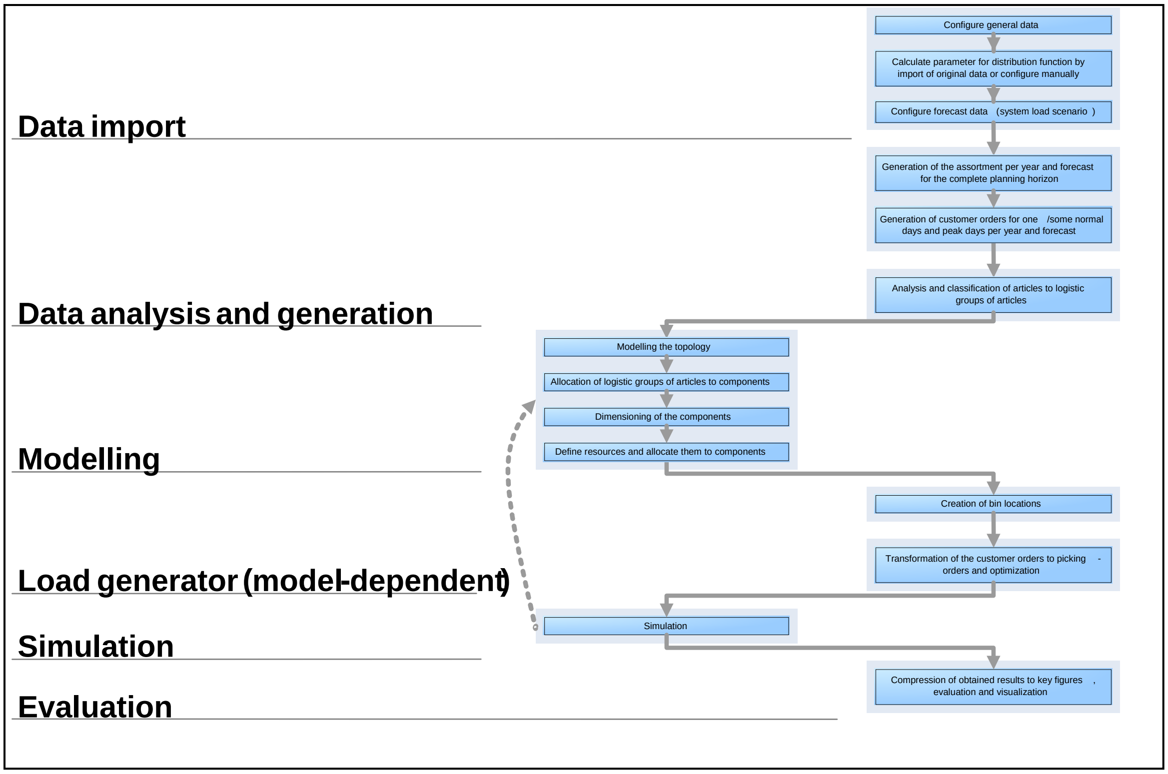

Figure 1: Process model of a simulation-aided rough planning

Data import / Data analysis and generation / Modelling / Load generator (model-dependent) / Simulation / Evaluation

First of all, the so-called planer's model world had to be created, as basis for a simulation-aided planning development. This is a view on those elements and components which the planner usually uses to design order-picking systems. For this purpose, a modelling paradigm was developed which at first consisted of a topology level which represents the four main functions of an order-picking system: picking 1st level, picking 2nd level, preliminary picking and consolidation. In each of these function areas component areas are generated with one order input point each. According to the function area each component area can hold one or several components connected in series. For this purpose, a total of 7 types was defined and clearly described for the planner of order-picking systems. Each component can exist of one or several zones whereas these zones always have exactly the same technology and organisation. The actual core picking process is carried out within one of these zones.

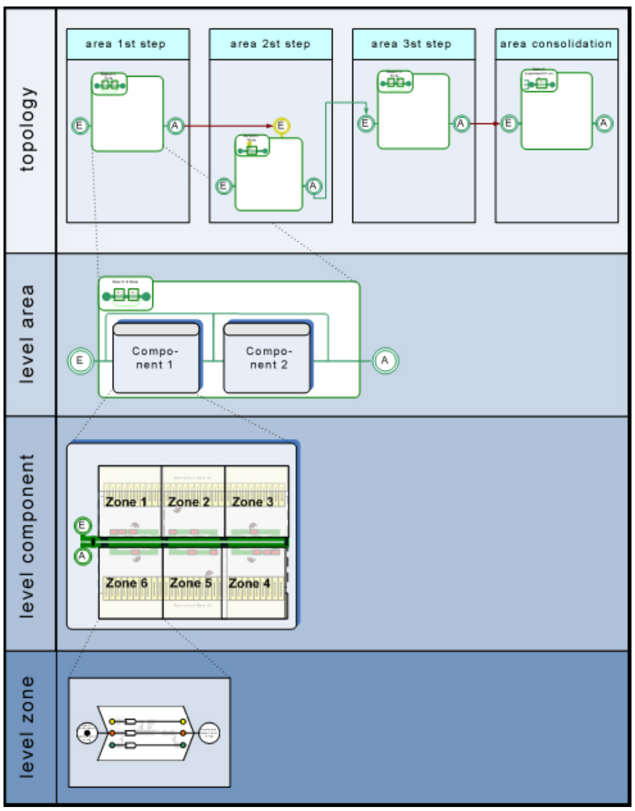

Figure 2: Modelling paradigm

Level zone / Leven component / Leven area / Topology

The procedure is described by means of the *component type 1*: *Conventional order-picking with statical provision*: The type 1 corresponds to the man-to-goods principle, where the picker moves the order tray to the pick-up units. The output parametrisation assumes just one zone for the complete provision warehouse as well as a purely manual procedure without a transport system for the order bins.

From the picker's point of view the picking process looks as follows:

- Collects the collection bin or transport unit at the basis:
  Here, the time consumption corresponds to the component parameter BasictimeZoneStart, which is calculated by MTM (Method-Time-Measurement).
- Moves to the first pick-up station:
  Based on the bin status report a given time consumption according to distance and speed in x and y direction is booked
- Retrieves goods at pick-up station:
  The retrieval time is calculated by MTM and saved as standard value in each component. The number of necessary retrieval processes depends on the number of retrievable items (parameter *NumberGrips*).
- Places goods into the collection bin:
  The standard time for this process was calculated by MTM and is saved in each component. If the retrieval covers several order items, like in series picking, the time is considered once for each item.
- Moves to the next pick-up station:
  According to the order information and the saved routing strategy the distance to the next pick-up station is calculated and the walking speed of the picker is booked as time consumption.
- Moves to basis:
  After the picking of the last item the return to the basis is booked as time consumption.
- Transfers collection bin:
  When the picker arrives at the basis he/she transfers the collection bin or the transport unit for the collection bins of a picking series to the next zone/component. Here, the time consumption is booked according to the parameter BasictimeZoneEnd calculated by MTM.

Further predefined component types are:

- *Zone-picking with statical article provision*
- *Operator station with dynamical provision from upstream warehouse*
- *Inverse picking with dynamical provision from upstream warehouse*
- *Mobile picking with statical provision of articles and orders*
- *Central picking with fixed transfer stations*

The single model elements are then interconnected. Each simulation model consists of sources, areas, components, connections, and sinks. Some of the simulated processes are independent of the dynamics, in the simulation as well as in reality, and thus can be precalculated and deliver the basic data for a future simulation. Examples for the so-called preprocessing are all net expenditures for the picking of an order including basic, routing and gripping times. Another advantage of preprocessing is the fact that this net picking times can also be used to plan the assignment of resources so that the number of working hours per simulation run and area/zone are known.
When the simulation runs are finished the acquired data are compressed into investment and costing values which back up the choice of a planning variant.

6 Dimensions of the planning task

Several methods representing the different order-picking systems can be developed for a planning project. In a system load scenario the changes of the article and delivery structure are defined with regard to time and different assumed developments (e.g. increase of the article range by 10% each year and reduced delivery items by 30%).

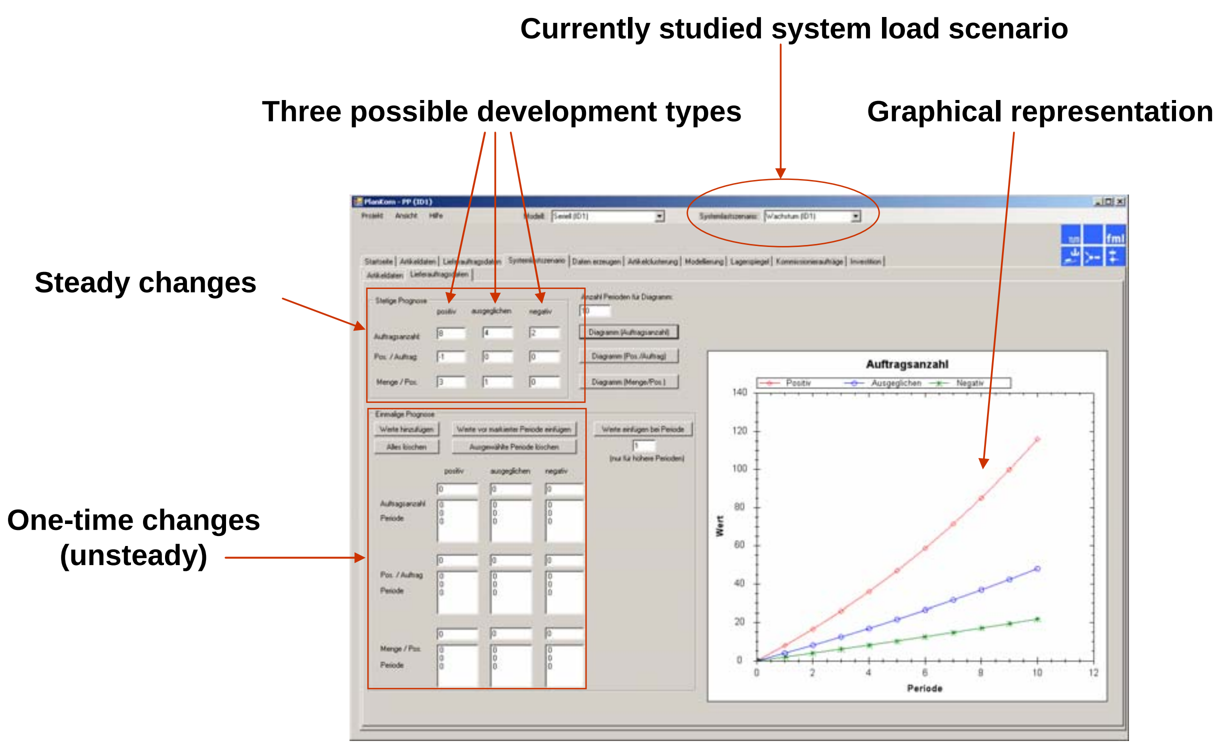

Figure 3: Developments of the characteristics of a delivery order

Currently studied system load scenario / Three possible development types / Grafical representation / Steady changes / One-time changes (unsteady)

A simulation run looks as follows, no matter whether on a normal or a peak day:

1. Model information about areas, components, technical dimensioning and parameters are loaded
2. The model is generated (areas, components, zones, resoures, links)
3. Load data for the model are loaded and simulation data are precalculated.
4. A working day (from the point of time when the first resource (employee) starts to work up to the end of work of this resource (employee)) is simulated. In line with the simulation the times for the various events are saved in a database for the future determination of key figures.

6.1 Reference scenarios

In order to validate the constructed, simulation-aided planning environment and to generate general key figures and design rules four reference scenarios were developed. These reference scenarios were selected and formulated with the aim to use as many different simulation components and data generation configurations as possible. Two scenarios are based on the real systems of participating industrial partners (*conventional picking vs. picking in zones* as well as s*erial vs. parallel organisation forms*). The other two were defined freely and focus on the deduction of design guidelines (*optimized number of zones for zone picking* as well as *Single-level vs. two-level order-picking*). The last two scenarios showed the most that the definition of key values and design guidelines often requires various environmental key values so that the representation of these guidelines in most cases is not generally admitted.

6.2 Findings of the simulation-aided rough planning

The test series in the scope of the reference scenarios partly showed uncommon curves in the key value diagrams of several models. These were partly due to stochastical fluctuations. Because of this effect the results varied by up to 5% despite of the same parametrisation. This leads to the conclusion that a simulation-aided planning environment is suitable for the comparison and selection of a system only to a limited extend. A difference of costs per picking item by 5%, for example, is no sufficient basis for a decision in favour of or against a certain system.
To support the results of an experiment it is sensible to carry out several simulation runs with the same parametrisation – even if this would prolong the planning phase.
The research project also revealed that for a variety of planning tasks the optimal model for the generation of definite key values could be parametrised only after several iterations where the results of each simulation run were challenged and adjusted by the planner.

7 Outlook

After the demonstrator-concept had been developed, in the next step this concept will be changed into a usable, inexpensive and efficient planning software tool for SMEs. Main emphasis is given to realisating and integrating the developed functions and modules into a service-oriented architecture which offers different module services (e.g. prognosis modules, simulation modules, load generation modules, ...). A future target could be to develop a kind of component architecture where strategies/rules and modules can be added to certain levels. Such an architecture could be integrated into a warehouse management system or upgrade the system in the form of a goods receipt, replenishment or shipping area.