

PERFORMANCE CALCULATION FOR ORDER PICKING SYSTEMS BY ANALYTICAL METHODS AND SIMULATION

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Abstract: “First, the order picking then the stock planning – In the order picking area the most stuff is usually employed. Here the customer service and the logistics quality are decided. The highest costs incur here.” [5] The planning of an order picking system is characterized by the complexity of the system. All attempts to standardize the planning process failed so far. The aim of two research projects at the department for Materials Handling Material Flow Logistics of the Technische Universität München is to develop a holistic planning method for the system planning (rough planning) of order picking systems. Thereby two different methods of resolution are examined. In the first project the performance assessment is made by the simulation of the system. In the second project analytical methods for performance assessment are used.

1. PLANNING OF ORDER PICKING SYSTEMS

The order picking is the central function of the warehouse logistics and has significant influence on areas like production and distribution [7]. Despite the trend towards automation, order picking is a costly area in modern logistics systems [13]. This is mainly due to the high personnel section [11]. In order picking systems from a total quantity of items (the assortment) subsets are assorted by a customer order and then sent to the customer [11] [14]. These are the most difficult tasks of the in-house (intra) logistics [4]. This is due to the complexity of order picking systems, because there is a multitude of ways to realize the picking task [11] [2] [10]. Due to the requirements of the order picking, the most efficient mix of the spectrum of order picking technologies has to be selected. It is important to achieve a high delivery quality and simultaneously a high economic efficiency [7]. Often the right solution does not consist only of one specific order picking technology, but from two, three or four different order picking technologies, which can be arranged in an useful combination [1] [2] [10]. Such hybrid or heterogeneous order picking systems allow to adapt the complete system to the specific requirements. There is no standard solution for picking. There is more than the possibility that standard modules, like an automatic small-parts warehouse with picking stations, can be used [2]. It can be deduced, that the planning of order picking systems is the search for a unique solution, which best meets the requirements [1] [10] [7].

2. REQUIREMENTS FOR AN ORDER PICKING SYSTEM

The requirements for an order picking system become higher and higher. The requirements increase due to smaller individual orders, followed by a higher delivery frequency [9] [2] [7] [3]. Furthermore, the growing diversity of items and the high standards of the material availability advance the requirements. The delivery times will be shorter and shorter and thus the cycle times too [1] [2] [7] [3]. Also additional services, such as the labelling of goods for customers, increase the requirement for order picking systems [9].

For successful planning an exact as-is analysis is the precondition [2]. The as-is analysis and the aim planning include the quantification of the requirements and a quantity structure for the planning is created. These data can be divided into assortment structure, article structure, access structure, order structure and shipping structure [6][7]. The requirements for an order picking system can be modified after the planning horizon. Within the planning the development has to be assessed. Here it is recommended to work with various scenarios. Thus different business developments can be taken into consideration and the adaptability of an order picking system can be evaluated [12].

3. ADVANTAGES OF THE USE OF COMPUTERS

Often known solutions are used. For example, companies such as Vanderlande or Dematic use planning systems, which propose system variants due to requirements (key parameters). These systems use data of past projects. All attempts to classify the order picking solutions and to standardize the planning process failed so far [2]. Within the system planning, often systems variants are approximately dimensioned and evaluated. Usually the planner uses averaged data, which are extrapolated linearly for the planning. This kind of planning has reached its limits and can not satisfy the actual requirements for the planning of order picking systems [8]. The use of integrated planning software from the analysis of the actual data, by defining scenarios, the dimensions of the order picking system, the determination of performance and the calculation of the investment and costs can shorten the planning process [5]. By the automation of the performance calculation more variants can be considered. This will reduce the risk that beneficial variants are not examined.

4. INNOVATIVE APPROACHES FOR THE SYSTEM PLANNING OF ORDER PICKING SYSTEMS

Two research projects at the department for Materials Handling Material Flow Logistics of the Technische Universität München deal with the system planning of order picking systems. In the first research project, which is supported by the AiF

(“Arbeitsgemeinschaft industrieller Forschungsvereinigungen”, in engl. consortium of industrial research associations), simulation is used for the planning. 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 considered over hours, days, weeks or years, as well as changes in the item and order structure. In the second research project, which is supported by DFG (“Deutsche Forschungsgemeinschaft”, in engl. German Research Foundation), analytical methods are used for the performance analysis. The centre of the analytical model is a process description with MTM (Methods-Time Measurement). By using cluster and statistical analysis the parameters for MTM analysis are determined. Through the clustering of orders the requirement structure of the order picking system can be illustrated exactly.

5. IDENTIFICATION OF OUTPUT BY SIMULATION

For the simulation of an order-picking-system the orderlines for every picking-region, the topology of the picking regions and the principle of picking for every picking-region is needed. With these three parts of information the information-, material-flow- and organisation-system is fully described for simulation.

The statically dimensioning of picking-regions is depending on the assortment (inclusive the minimum ranges of every article) which is provided in this region for the picking process. Principles of picking-systems amongst others are

- the classical person-to-goods picking with providing articles statically in small parts storage racks or pallet racks without automation technology,
- the local picking with providing articles statically, also referred to as “zone-picking”,
- the classical goods-to-person picking in a picking station, which is provided by automatic small-parts warehouse or automatic high rack warehouse,
- the inverse picking,
- the person-to-goods picking with manned rack feeders

At the department for Materials Handling Material Flow Logistics a library of modules named “BauKom” was composed of the above-mentioned principles under considering the cognition of the AiF-project No. 14601. These modules are used for picking studies by simulation. In each simulation module several parameters can be set, which amongst others are describing the statically dimensions as number of zones, lanes, columns and rows with appropriate lengths of the bin locations as far as the moving strategy of the picker. Subsequent from the simulation module the represented picking-system is build up, which can be connected with other modules if required. By connecting various simulation modules appropriate hybrid and multi-level picking systems can be created.

To ensure an continuous flow of planning and the practicability for the planner without consolidated knowledge, the library of modules for simulation was integrated in an planning environment named “PlanKom”. This planning environment is implemented as windows application by the programming language C# of the .NET-Framework. PlanKom performs among the building of key figures also the complete preparation of data, which runs from the creation of customer orders to the transformation of them with the result of picking-orders. The creation of customer-orders is based on an assortment created by the planning environment. In front the planner has to define the horizon of planning and possible variations of the company performance for the purpose of data extrapolation. From this we get a lot of times of inspection. By the planning environment an assortment and customer-orders have to be created for every single time of inspection. To ensure the execution of transformation of the customer- to picking-orders a modeling environment is implemented in the planning environment, which can be used for defining the variations of picking systems furthermore referred as models. In these models several parameters have to be set, to ensure the automated build-up of the simulation model. By Knowledge of the topology of the picking system, the allocation of articles to picking-regions and the information first or second level according to an article-oriented picking we have developed a general algorithm which can determine picking-orders from customer-orders for every possible hybrid and multi-level picking-system.

The basic time used by simulation for picking-order acceptance and hand-over once in one zone as well as the supposed time for picking of one or some withdrawal units is deposited in every simulation module. But for precise solutions we prefer to calculate the basic time for acceptance and hand-over of one picking-order by MTM(Mean-Time-Measurement)-operation.

While simulation is running for every picking-orderline a starting and completion timestamp is taken as well as the part of basis-, walking- and picking-time according to this orderline. Afterwards in evaluation key figures could be build in any detailed level. For example it is possible to apply the item per hour or the workload of the picker to the whole picking-system or to one particular zone in the picking system. But also investigations for specific order-types as customer orders with more than ten orderlines e.g. could be progressed easily. Beside the mean value of a key figure also the minimum and maximum could be collected. With this auxiliary tool comparison of systems as well as optimizations of a specific variant of picking-system can be performed whereby the process of planning gains reliability.

6. ANALYTICAL PERFORMANCE CALCULATION

As in the first project, an order picking system consists of various modules. Each module represents an order picking process, which are linked depending on the

form of organization. The performance of an order picking system can be defined as picks per time unit. The time required to handle an order consists of the basis time, the picking time and the walking time. Thus, the performance (P) is defined as follows:

$$P (n^{Picks}, n^{orders}) = \frac{n^{picks}}{t^{pick}(n^{picks}) + t^{basis}(n^{orders}) + t^{way}(n^{picks}, n^{orders})} \quad (1)$$

For the determination of the performance of an entire order picking system the system is divided in the individual modules (1, ..., i, ... K) and the performance of each module is determined separately. For each module three different time slices can be defined.

Picking and basis time - From the available data the necessary parameters for the calculation of times are determined (volume, weight, number of orderlines, positions...). Each module has standard processes for the basis and picking time. These processes can be adapted in a certain extent by the planner. The time for the execution of the two processes will be determined on a MTM analysis. This will be done by the planning software. The result is a retrieval time per pick unit (t_i^{Ent-GE}) and a deposit time (t_i^{Ent-GE}), which together determine the picking time and the basis time per order. The whole picking time of an order can be determined by the characteristics of an order (e.g. average number of orderlines, average quantity of orderline and retrieval quantity per pick) The basis time per order depends on the number of pickers involved in the process. If a picker works alone on an order, the basis time comes up once. If more than one worker deals with the order, a multitude of the basis time is required.

Walking time - Generally, the way covered during the order picking is divided into basis way (s_{Bi}), lane changing way (s_{GW}) and lane way (s_{Gi}). The length of the basis way depends on the location of the basis. The lane changing way depends on the way strategy and distribution of the item on the lanes (fast movers concentration, uniform distribution). The same is true for the way in a lane. From the assortment data and the modelling of the order picking system the parameter numbers auf lanes, lanes length and the distribution of item (access- frequency) for each module and its zones will be determined, for the calculation of the lane way. On the basis of picking orders it will be determined how many orders can be worked on in every zone with how many orderlines. For the calculation the maximum of orderlines (n) of each zone has to be handled. With these data the calculation of the lane way is possible.

Calculation of lane way for the zone picking - The calculation of the lane way will be demonstrated by an example. The layout of one picking zone is illustrated in Fig. 1.

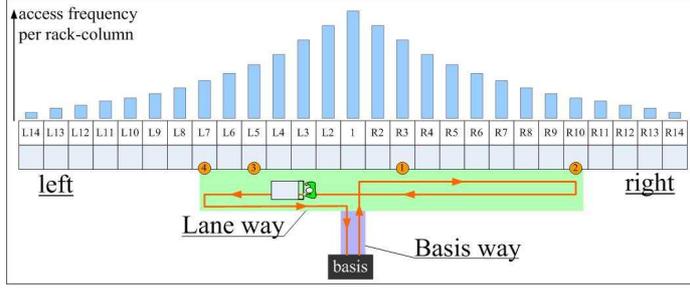


Figure 1: layout of one picking zone

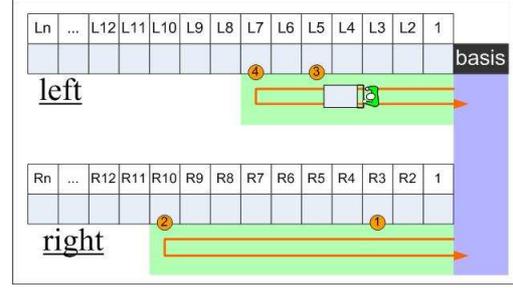


Figure 2: abstract layout of the zone

It is discernible, that the items with the highest access frequency are stored in the middle of the rack, opposite the basis. On average four orderlines will be picked in one zone. If the zone splits in the middle, this zone may also be understood as one zone with two lanes. Thereby the picker works according to the branch aisle strategy without iteration. The abstract layout of the zone is illustrated in fig. 2.

The lane way can be calculated by the random variable $X(n)$, which defines the maximum distance from the lane entrée, which must be covered by the picking of n orderlines. Because the picker must go to the right lane entrée after the tacking of the last position in the lane, the lane way is defined as follows:

$$s_n = 2 \cdot E(X_{(n)}) \quad (2)$$

Assuming that the distribution of access frequency in the lane can be described as standardised exponential distribution, the lane way is calculated as follows (according to Sadowsky [11]):

$$s_n = 2 \cdot L \cdot \frac{1}{\lambda} \sum_{k=1}^n \frac{1}{k} \quad (3)$$

In the chosen example, it may happen that all four orderlines will be picked in lane one. Also it may happen, that one orderline will be picked in lane one and three orderlines in lane two. Thus, the probabilities are calculated for all possible combinations of two lanes and four orderlines. The Laplace-probability $\rho(r)$ for the event has to be defined, so that just r of totally n orderlines are picked in one lane. The result of this is that the expected lane way will be calculated as:

$$s_n^{erw} = 2 \cdot N_G \cdot \sum_{r=1}^n \left[\frac{\binom{M_G}{r} \cdot \binom{M - M_G}{n-r}}{\binom{M}{n}} \cdot L \cdot \frac{1}{\lambda} \cdot \sum_{k=1}^r \frac{1}{k} \right] \quad (4)$$

The symbols will be explained in the following numerical example. The analysis of the database shows the following data for one zone.

N_G	=	2	number of lanes in the zone
M_G	=	500	number of items in one lane
M	=	1.000	number of items in the zone

L	=	50	length of a lane
λ	=	5	parameter of exponential distribution
n	=	4	number of orderlines

If the values are set in formula (4), the expected lane way is 56,05m. The walking-time is $56,05\text{m} \cdot 0,9 \text{ sec} \cdot \text{m}^{-1} = 50,44 \text{ sec}$ ($0,9 \text{ sec} \cdot \text{m}^{-1}$ is the MTM-Vale for walking). The basis time was calculated by an MTM-analysis and is 26,34 sec per order and zone. Also the picking time was calculated by an MTM-analysis and is 14,4 sec per orderline. Thus the performance of the order picking system is 107 picks per hour.

7. EXAMPLE

To clarify the course of action of both methods of resolution a particular planning task is shown next. The specific concern has already decided to invest into a picking system with classical person-to-goods picking with providing articles statically in small parts storage racks after a detailed system comparison. Now the concern wants to know how many zones and how long a zone should be. The assortment and customer-order structure is given. A Zone should be realized by flow racks, with four places on top of each other. For every article one place is needed. The zones will be connected by a material handling system for the boxes.

In the following figure the underlying article- and customer-order-structure is described. The article structure will be constant. The order structure will be varied in the number of orderliness per order.

The assortment for the considered picking system consists of 3.000 articles, which are provided in boxes with the dimensions 40x60 centimeters. The access frequency is as shown in fig 3 moderate exponential distributed.

To show the effect of different sizes of order we vary the number of orderlines per order. Five different order structures are investigated. The number of orderliness per order is varied from one over four, eight, 12 and 16. The number of orderlines remains constant so the number of orders has to be changed for every investigation. The number of items per orderline will be disregard and set to one. A larger number of items per orderline

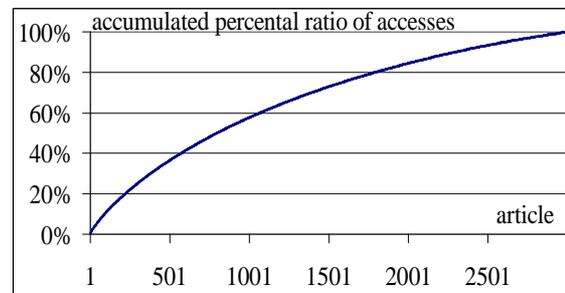


Figure 3. access frequency

Table 1. investigated order structures

order structure	number of orders	number of position	picks per position	total of position
I	8.000	1	1	8.000
II	2.000	4	1	8.000
III	1.000	8	1	8.000
IV	667	12	1	8.004
V	500	16	1	8.000

would only have effects on the picking time but not on basis or walking time. Six models are taken into consideration which only differ in the number of zones and in

order that in the length of a zone. The number of zones is varied from one over two, four, eight, 16 and 32. These models are defined in the modelling environment and furthermore saved in the subordinated database.

The simulation environment gets the needed parameters from the database. Needed parameters are for example the module identities and the topology as far as the simulation runs which have to be carried out. For each simulation run the complete module information and the list of orders has to be reloaded. This example contains only one module. This module fetches the parameters like the number of zones or the number of bin locations in a lane. With this information the fully parameterized module builds up a container loop with as many zones as defined (e.g. fig. 4 shows the container loop initialized with four zones). The information of the number of bin locations is needed for the initialized built-up of each zone. An example of a built-up zone is shown in fig 5. After this the first simulation run can be executed. During the simulation run time slices are selected and saved in the database at the end of each run.

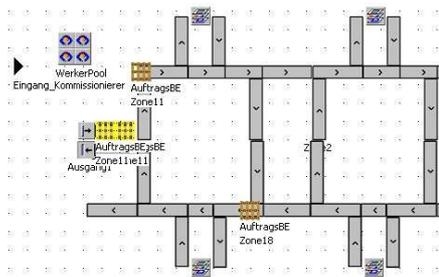


Figure 4. container loop with four zones

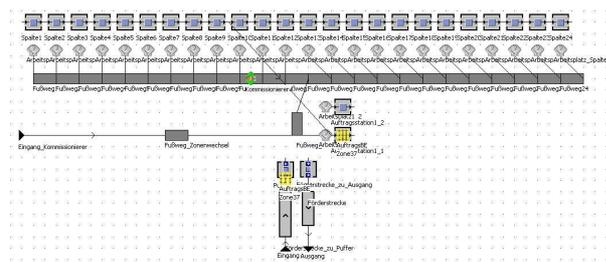


Figure 5. modelling the order-picking zone

The analytical calculation is done like chapter 4. The times were calculated for each zone of a model. After this the average time was calculated.

8. RESULTS

The results determined by analytical methods and by simulation are compared in the next figures. As expected the average basis time per orderline increases by increasing the number of zones (fig. 6). There are no magnificent differences between our analytical method and the simulation. Also the expected opposite direction of the average walking time by increasing the number of zones can be detected (fig. 7). On closer inspection the average walking time determined by analytical methods is higher than the time determined by simulation. The quality developing of both values are the same. The quality to decide in how many zones the system should be divided, the sum of average basis and walking time per orderline is calculated and shown in fig. 8.

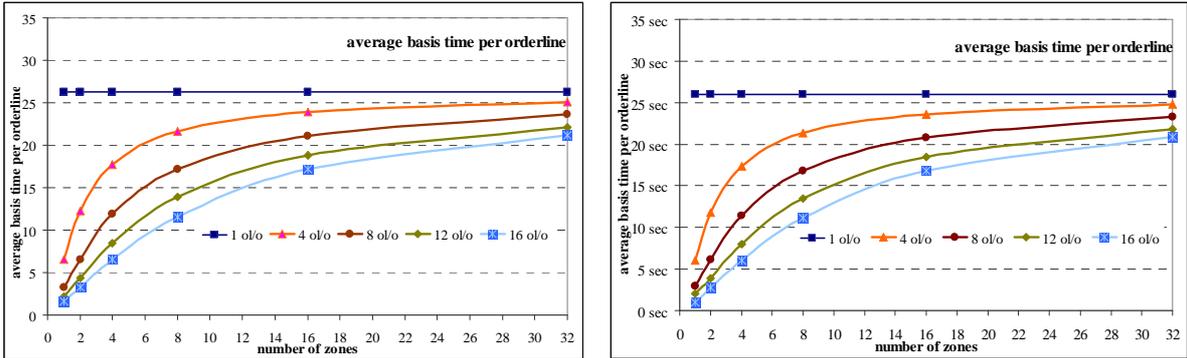


Figure 6. analogy of determined average basis time per orderline by analytical methods (left figure) and by simulation (right figure)

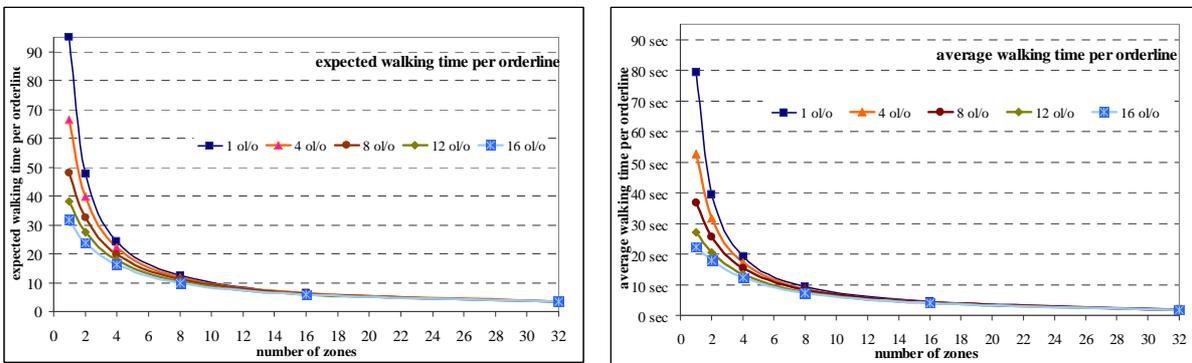


Figure 7. analogy of determined average walking time per orderline by analytical methods (left figure) and by simulation (right figure)

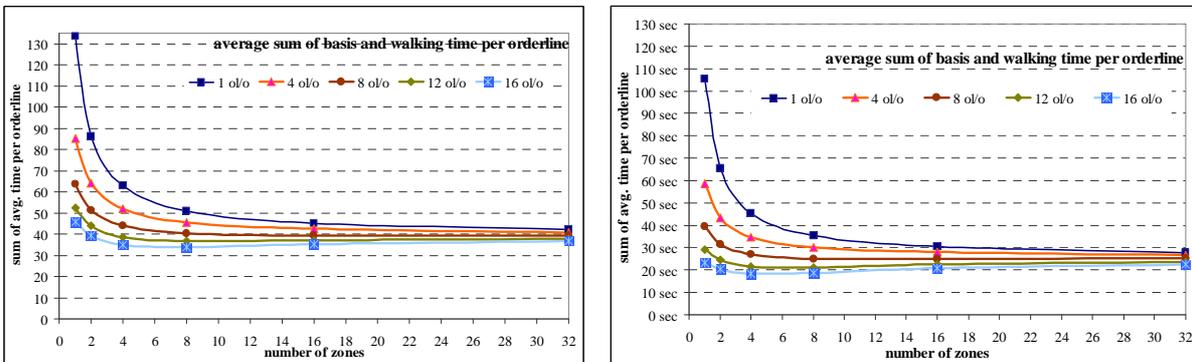


Figure 8. analogy of determined sum of average basis and walking time per orderline by analytical methods (left figure) and by simulation (right figure)

9. OUTLOOK

By using afore mentioned systematic techniques versions of picking systems can be calculated or simulated in a much shorter time. The planning risk can be minimized by inspecting changes in the actuating variables towards picking systems. Additionally, by the automatic calculation of the performance it is possible to compare more alternative versions. From this it follows that the reliability of planning in-

creases. Furthermore we aspire to compare picking systems depending on different techniques, as the case may be modules as defined, depending on changing actuating variables. One result of this new aim should be new style guides for efficient picking systems.

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