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MATERIAL FLOW ENHANCEMENT IN PRODUCTION ASSEMBLY LINES UNDER APPLICATION OF ZONED ORDER PICKING SYSTEMS

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Introduced research work relates to the possibility of material flow enhancement in production systems, with the apostrophe on material order picking in production assembly lines. The paper presents basic rules and the results related to formed computer models of zoned order picking systems under the application of developed bound cavities method.

Key words: assembly lines, material flow, order picking, bound cavities method

INTRODUCTION

The intense production development causes more and more expressed necessity for adequate solutions in the field of material transport and storage. The material flow within production system denotes material flow within the boundaries of production system and its timely and organizational-interconnected. The aim in all material flow processes is to achieve shortest possible cycle with smallest possible stored quantities of raw material (at the entrance) and finished products at the exit of production process [1,2]. This request is especially stressed when producing families of similar products (electric motors, toothed gears, …) facing great diversity of daily orders. Since it is not rational solution to store large number of different device models, in the warehouses are kept single parts and subassemblies, being picked, sent to the production line and assembled according to daily orders. Because of the necessity to assure timely adjusted supply of production system with needed resources in all the phases of production process, efficient order picking system for material supply (in terms of type and quantity) is inevitable.

According to performed research work in the field of material flow, most important activity, where improvements can be implemented, which is very hard to be entirely automated, where an amply application of manual work is present and which causes significant time and money losses, is right the order picking [3]. Order picking accounts for as much as 55 % of the total material flow operating expense [4].

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THEORETICAL BACKGROUND

Zone picking is a flexible and highly structured order picking concept. Zoning is the problem of dividing the whole picking area into a number of smaller areas (zones) and assigning order pickers to pick requested items within the zone. Order pickers are assigned to a specific zone, and only pick items within that zone. Orders are moved from one zone to the next after the picking from the previous zone is completed. Usually, conveyor systems are used to move orders from one zone to another one.

The main idea in zone picking is that the products are allocated into proper zones to equalize workload among all pickers so that each picker has about the same workload. If the workload is not balanced, it may happen that some pickers keep busy with too much workload while the others remain idle without the order to deal with. The unbalanced workload results in long picker time and less throughput. In his study C. Jane presented a heuristic algorithm for balanced assignment in a zone picking system [5]. Here, historical customer orders are examined and the items are assigned to storage zones in order for each zone to have the workload as equal as possible. This approach is expected to provide balanced workload among zones on the long term base. Using simulation studies, C. Petersen showed that the zone shape, the number of items on the pick-list and the storage policy have a substantial impact on the average travel distance within the zone [6]. C. Pan and M. Wub developed an analytical model for the pick-and-pass system by describing the operation of a picker as a Markov Chain for the estimation of the expected distance travelled of the picker in a picking line [7]. Based on the proposed analytical model, this study derives properties of storage assignment and proposes three algorithms that optimally allocate items to storages.

An alternative to zoning with fixed zone size would be a more dynamic way of zone sizing and assigning order pickers to zones. The "bucket brigades" is an example of this. The main advantage of bucket brigades is that they are self-balancing with respect to the workload. P. Koo developed the method which he named "zoned bucket brigades picking", meant to be the combination of classical zone order picking principle and bucket brigades order picking principle [6]. The picking line is divided into m zones, at boundaries of which interface storages (buffers) are located, in total m-1 of them.

ANALYSIS

The performance of an order picking system is typically determined by seven factors: batching, picking sequence, storage policy, zoning, layout design, picking equipment and design of picking information [7]. When performing order picking, a picker is moving along the picking line, stopping at picking places, where an item is to be picked for actual order (marked with black spots in Figure 1), and passing by the places where there is nothing to be picked – empty spaces [8]. If the number of items, which are to be picked, is small compared to total number of items, there is great number of empty spaces. Also, there are the regions with successive places where there is not necessary to take the items for the actual order (see Figure 1, the places 12-13 and 18-20). These regions are called "bound cavities".

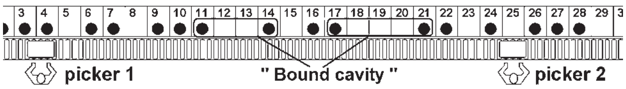

Figure 1 Picking line with 2 pickers

Within picking time structure we distinguish between the times for item picking and the times for picker travel. If we analyze the work of two pickers in the system with zoned pick and pass order picking, it is clear that the time periods concerning item picking are inevitable, which means that they can only be distributed among pickers. Regarding the travel time, if technical predispositions exist to send the tote via conveyor from the first picker to the second one, it would be optimum that zone interchange happens on the spot with the longest picker travel without item picking, which means on the spot with the longest bound cavity (according to the Figure 1, from places 18 to 20). In this way it would be possible to avoid regarding the activities and also used time, the travel of the picker in both directions, in the zone where there is anyway not necessary to pick any items.

This is the reason why the bound cavities method was developed, which strives to have the change of pickers, or zones, performed precisely at the position where the largest bound cavities occur. In order to implement the method, a pick to light order picking system is required with 2 roller conveyors, where the second one, which is the one with the drive, is located under the picking locations in the area next to the first one, along which the pickers push the totes during picking. Regarding activity structure and used times in the zone order picking system with 2 pickers, we distinguish between following times, according to Figure 2:

- t^I_{1R} t^I_{2R} - picker engagement time for the order # i,
- t^I_{1P} t^I_{2P} - picker return time for the order # i, depending on the place where next order fulfilling begins, if it is not the place 1,
- t^I_K - time necessary for the tote to travel via roller conveyor from the end of the first zone to the beginning of the second zone in the case of order # i.

The calculation of these times, and the other necessary for the simulation (total time necessary for picking, total waiting and blocking time, time delay of pickers) is presented in reference [10].

If we consider the beginning of the picking process and analyze which order from the group of treated orders should be dealt with as the first one, we come to the conclusion that it should be the order minimally engaging first picker, in the course to minimize waiting time of second picker. On the other hand, if we analyze which

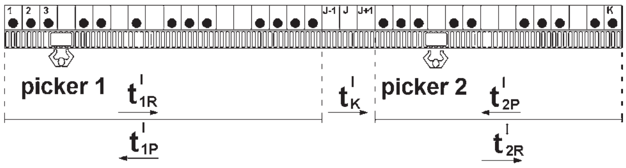

Figure 2 Basic times in zone order picking system with 2 pickers

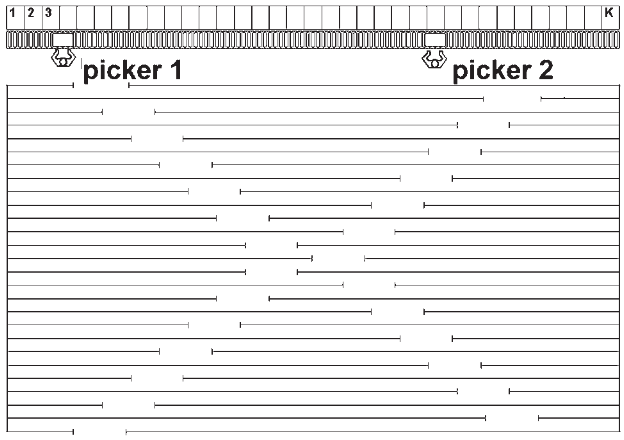

Figure 3 The sequence of order execution according to the X procedure of the bound cavities method

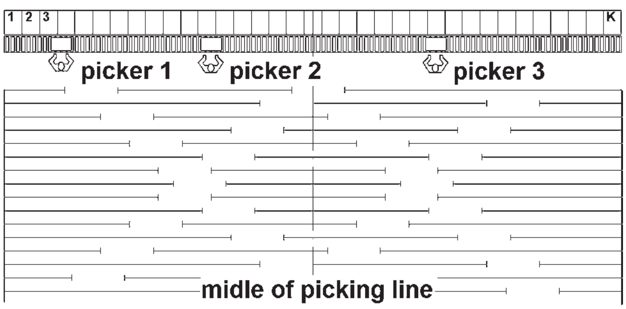

Figure 4 Double X procedure of the bound cavities method

order from the group of orders should be dealt with as the last one, we come to the conclusion that it should be the order minimally engaging second picker, in the course to minimize idle time of the first picker. To avoid or to minimize first picker waiting time after the first order, where the engagement time of first picker is much shorter than engagement time of second picker, first picker should have much more to do in the second order than second picker. Similar situation is encountered at the end of the process. In order to meet these requirements, we come to a diagram of the sequence of order execution during order picking which resembles the letter X, hence the name of the procedure, Figure 3, where the lines represent the loads on the pickers. The developed method can be applied to zone order picking systems with any number of pickers, while Figure 4 shows the sequence of order execution for a system with 3 pickers.

RESULTS AND DISCUSSION

The mathematical model of a zone order picking system was created in Microsoft Office Excel. Simulations were performed on the created models, where calculated were the distances traveled by the pickers and the total time necessary to execute the picking of a group of orders [11]. The models made calculations using a picker travel speed of 30 m/min, a roller conveyor speed of 1 m/s, a single item extraction time of 2 s, the time necessary to detect a light and press the button of a length of 2 s, and a width of a picking position of 0,5 m.

The models were formed for a system with two and tree pickers, while considered were variants with 20 and 50 orders in a group. The number of items in the picking line was 80 and 300. The average number of items that are extracted per order ranged between 25 - 30 % of the total number of items. In determining the boundaries of the zones, firstly adopted was the largest "bound cavity", but also created were variants in which 2 or 3 of the largest "bound cavities" within an order were considered, at which the adopted zone boundary is the one that provides for a more balanced load on the pickers.

In order to define the structure of the orders, sequences of random numbers with an exponential distribution were generated. An appropriate number of random numbers was generated for different variants, representing information on the location and number of items for extraction per individual order. Five repetitions were carried out for each variant.

Simulated were order picking systems with fixed zones, bucket brigades and dynamic zones (according to random sequence and an execution sequence according to the bound cavities method). The results for 2 picker systems are given in Table 1, and for 3 picker systems in Table 2.

Based on the results of the simulations on the formed mathematical models, the following can be concluded:

- an increase in the number of "bound cavities" that were taken into consideration (from 1 to 2 and 3) in determining the boundaries of the zones, has led to a reduction in picking time in all of the variants (up to 2,45 %),
- systems that used the largest "bound cavities" as the zone boundaries, with a random sequence of execution, showed significantly poorer results than the system of bucket brigades in all of the variants,
- the distances traveled by the pickers were significantly reduced by using the "bound cavities" method (up to 7 %),
- an increase in the number of bound cavities that were taken into consideration reduced the picking time in all of the variants, but the distances traveled by the pickers slightly increased.

Table 1 **Results for a system with 2 pickers**

orders items		20 80	50 80	20 300	50 300
Average total picking time /sec					
bucket brigades		2 376	5 771	8 988	22 238
fixed zone, random sequence		2 516	5 941	9 167	22 517
fixed zone, X procedure		2 492	5 878	9 101	22 356
bound cavities method	1 cavity, random sequence	2 581	6 532	9 870	23 712
	1 cavity, X procedure	2 498	6 183	9 481	23 404
	2 cavities, X procedure	2 404	5 739	8 890	22 072
	3 cavities, X procedure	2 347	5 653	8 768	21 934
Average picker traveled distances /meter					
bucket brigades		1 361	3 397	5 517	14 024
fixed zone		1 312	3 289	5 418	13 867
bound cavities method	1 cavity	1 262	3 153	5 362	13 712
	2 cavities	1 282	3 252	5 381	13 802
	3 cavities	1 291	3 237	5 408	13 819
Average number of different item		19,1	19,3	68,1	67,6
Average total item number		25,3	24,9	86,2	86,2

Table 2 **Results for a system with 3 pickers**

orders items		20 80	50 80	20 300	50 300
Average total picking time /sec					
bucket brigades		1 575	3 984	5 970	14 899
fixed zone, random sequence		1 672	4 067	6 178	15 189
fixed zone, X procedure		1 655	4 031	6 115	15 067
bound cavities method	2 cavity, random sequence	1 721	4 317	6 511	15 978
	2 cavity, X procedure	1 621	4 212	6 432	15 807
	3 cavities, X procedure	1 559	3 972	6 003	14 915
	4 cavities, X procedure	1 583	3 837	6 021	14 798
Average picker traveled distances /meter					
bucket brigades		1 361	3 397	5 517	14 024
fixed zone		1 270	3 192	5 334	13 634
bound cavities method	2 cavity	1 226	3 087	5 257	13 513
	3 cavities	1 242	3 162	5 314	13 562
	4 cavities	1 257	3 128	5 321	13 571
Average number of different item		19,1	19,3	68,1	67,6
Average total item number		25,3	24,9	86,2	86,8

CONCLUSIONS

In this paper, one possibility of material flow optimization within the production system is presented.

Developed models of material flow in zoned "pick and pass" order picking systems were presented. According to acquired savings in total picking paths and times of the picker, it can be concluded that developed "bound cavities" method leads to improved characteristics of order picking system and, through it, of the total material flow system within the production system.

Coming research work concerning rationalization of material flow within the production systems shall be oriented towards automation and elimination of manual picking.

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Note: The responsible translator for English language is Tanja Todorović, Faculty of Technical Sciences, University of Novi Sad