RESEARCH ON ANALYSIS, SIMULATION AND PROGRAMMING OF PICKING SYSTEMS

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ABSTRACT: The paper presents elements regarding picking systems, with a tendency to develop and innovate. Warehouses, generally, directly affect the supply chain to meet customer orders, Thus, the picking process is described based on economic elements and outlined using a video simulation.

KEYWORDS: warehouses, analysis, simulation, picking, systems.

1. Introduction

Space and time efficiency are generally the most important criteria for warehouses management. Logistics facilities, such as distribution warehouses, directly affect the ability of the supply chain to meet customer demand. The key task of a warehouse is to fulfill customer orders on time and at the lowest cost. Therefore, it is necessary to look for organizational and technological solutions to improve the warehouse processes, such as picking up orders, ensuring the smooth, fast and precise fulfillment of orders [1]. Order pick-up processes can absorb up to 60% of the FTE (full-time equivalent employees [2]) for all activities in the warehouse and can generate approximately 55% of costs [1]. For this reason, there is a need to minimize the time of fulfillment of orders, respectively, to maximize the productivity of picking processes.

2. General consideretions

2.1. Picking systems

Picking systems are classified according to different criteria - number of employees, type of picking process, order processing. Thus, there are order processing systems: manual; semi-automated; automated. In the manual system (from operator-to-product), picking operators move to locations and manually select items. A semi-automatic system (product-to-operator) moves products from storage locations to the picking station by internal means of transport, such as carousels, vertical lifting modules (elevators), SBS/ RS, mobile shelves, etc. Automatic control systems are able to fulfil orders without any human assistance (eg A-frame) [1].

In manual picking systems, manual order picking usually requires a number of operators working simultaneously. The order picking process is very laborious. System flow should potentially increase, but congestion is very common. Congestion in the manual pick-up system is related to the situation where the operator's tasks are interrupted by another operator, while all the requirements for a normal picking process are met [1]. The picking process is considered normal when the flow of orders is uninterrupted, all support systems (e.g. IT or equipment) are able to operate, and interfaces with other areas (receiving, sorting, etc.) are in operation [3]. A representation of the "operator-to-product" system is shown in Fig. 1.

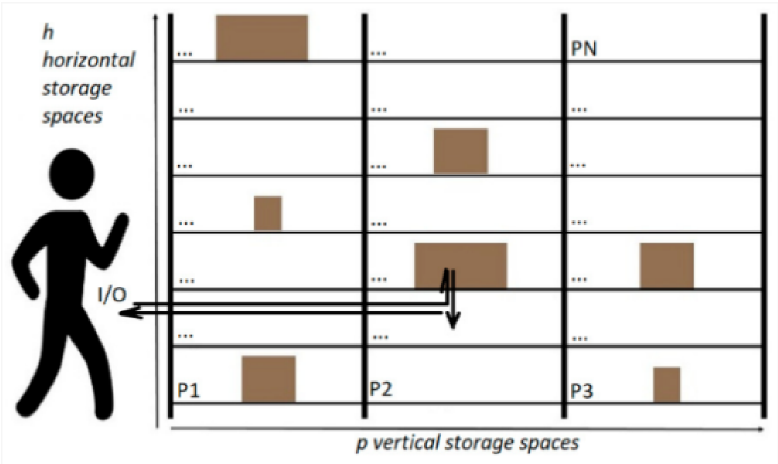

Fig. 1. Operator-to-part system [5]

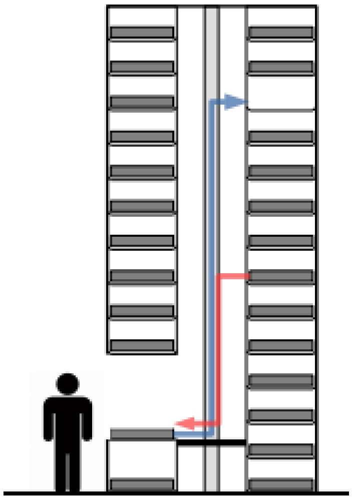

Fig. 2. VLM system [4]

VLMs are AS/ RS (systems of goods/ parts/ products) in which several trays are stored in a high rectangular prism. In these systems, the trays who containing the required parts are presented at the input/ output location (I/O). Trays in a VLM are generally divided into boxes to form individual storage locations. Once a tray is in the I/O location, the operator picks up the product from the box using indicators that point the correct box. A representation of a VLM system can be seen in Fig. 2 [4].

2.2. Analytical methods regarding the efficiency of the standard manual-picking system

The pick-face blocking approach (the place in front of each shelf, where the picking is performed) is based on probability theory and combinatorial calculations. One working element is the binomial coefficient to calculate the number of possible combinations of having j from K collectivities located in front of a shelf column at the same time. By weighting the probability that an operator is located in front of a shelf column, and at some point in time and taking into account all shelf columns, the following relationship is obtained to estimate the flow decrease [3]:

$$\lambda_{Decline} = \lambda_{OP} * \left(K - \sum_{i=1}^{c}\sum_{j=2}^{K}\binom{K}{j}(p_i * r)^j\right) \quad (1)$$

where $\lambda_{Decline}$ - the reduced throughput (order lines per hour), λ_{OP} - the throughput (order lines per hour) of a single picker without any congestion, c - the number of rack columns in the aisle, p_i - the pick frequency of rack column i, and r - the probability that a picker is picking, i.e. the portion of picking time with regard to the total order picking time.

A similar approach estimates additional travel time caused by in-the-aisle interferences. First, the extra time t_{add} is derived, so that, a picker K needs to walk in order to pass $(K - 1)$ other pickers, assuming that K pickers meet in a certain segment i. Note that one segment does not necessarily represent one rack column. After deriving the probability that K pickers interfere in segment i, the number of interferences I_K is calculated. In accordance with the calculations on pick-face blocking, the binomial coefficient is used and the percentage increase in travel time X_K is [3]:

$$X_K = \sum_{j=2}^{K}\binom{K}{j} * t_{add,K} * I_K \quad (2)$$

„Experiments show that for random storage travel time typically increases as much as 2% for less crowded aisles (5:1 ratio of segments to order pickers) and the increases can be as high as 7% for very crowded aisles (3:2 ratio). For class-based storage increases are much higher, namely 5% for less crowded aisles and up to 30% for very crowded aisles. Based on these results, an important element is derivation operational guidelines. In random storage there should be at most one picker per 3 meters of pick face. For class-based storage, there should not be more than two pickers per aisle, independent of the total length of the pick face as picks often tend to concentrate on a few rack columns" [3].

3. Simulation and analysis: Case study

„In the proposed models it is assumed that the items are stored with a random storage assignment, in both systems, and that the picking orders are processed individually, with a simple order picking strategy (and no batching). Moreover, both systems are considered to be always available, and the replenishment activity, needed for refilling the storage locations with items, is assumed to be performed in an additional time with a similar strategy for both systems" [7]. „All the indirect costs are assumed to be included in the total annual cost, and the throughput of the systems are described through a picking time, which could depend on the adoption of paperless picking technologies" [6].

"Two different terms are considered into the general total cost function: the fixed cost component is related to the annual costs of facilities, equipment and devices, including the indirect costs; on the other side, the variable cost component is connected to the resources necessary yearly to perform the required items picking" [6]:

$$TC^S = C^S_{fix} + C^S_{var} \quad (3)$$

where s = W for the warehouse with R3000 racks, mezzanine system, and s = V for the dual bay VLM [6].

The following case study shows the application of the economic model developed in the present paper. A step-by-step procedure is used to explain which data are necessary and how to compare the VLM system to the traditional warehouse with R3000 racks.

- Input data collection and estimation

The first step for the application of the method consists in retrieving the data that are needed for the formulations. General information and useful input data about the warehouse and the pickers are reported in Table 1.

Table 1. Information about the case studied

	Type A	Type B
Type of products	Spare parts, small parts, bushings, fasteners, etc. (usually car parts)	Various products, products for bathroom installations,batteries, etc.
Number of stored items	≈ 4.000 pcs.	≈ 3.500 pcs.
V [m^3]	≈ 180 m^3 on the mezzanine floor	≈ 180 m^3 on the ground floor
Q [picks/h]	220	360
N [lines/order]	12	25
t_1^W [s]	40.5	47
h_y [h]	1,800 h	3,600 h
k^W	2.59	1.47
SL^W	0.2	
C_{SP} [€/(hm^2)]	100	
C_{OP} [€/h]	35	

The studied warehouse has an area A^W of about 30 x 10 m^2, with a mezzanine where two different categories of products are stocked in R3000 racks. These two groups are stocked in the two floors: type A on the mezzanine level (with a resulting k^W = 2,59) and type B on the ground floor (then, k^W = 1,47).

Direct measurement method has permitted to estimate the average picking time per order line t_l^W. The total amount of time spent by the operators in the overall picking operations has been divided by the total amount of order lines performed in a period of 20 weeks, resulting in t_l^W = 40,5 s for type A and t_l^W = 47 s for type B.

From a first analysis of the available height of the warehouse area, it could be installed a VLM system of 10 m high, with 75 m^3 as storage volume V^V. From the information provided by different technical sheets and also confirmed by previous researches, typical values of t_{pick}^s, t_{fix}^s and t_{travel}^s for this kind of system are about 28 s, 60 s and 5 s, respectively. Thus, considering the different average number of lines per order N, the average picking time t_l^V is 28 s for the items of type A and 26 s for the items of type B.

- R_Q calculation and VLM applicability evaluation

Starting from the average cycle times per line t_l^W and t_l^V, it can be estimated the throughput ratio R_Q between the traditional solution and the VLM system for both cases: R_Q = 1.26 for the type A and R_Q = 1.56 for type B. Then, based on the input data available from the previous step, for the products of type A, R_Q^* (equal to 1.30) is higher than R_Q, and consequently, the traditional warehouse with R3000 racks is preferable.

For the other group of items (B) the throughput ratio is higher, R_Q = 1.56 In this particular case, R_Q^* = 1.23 because the warehouse works for h_y = 3,600 h/year. Thus, the VLM system is preferable for this group of products, since $R_Q > R_Q^*$.

- Area of application and system position representation

The VLM application areas for the two analysed cases, type A and type B, are reported in Fig. 3. For the items of type A, it can be seen that there is no VLM area of application, and the position of the adopted solution, related to V^V = 75 m^3, lays on the area of the warehouse with R3000 racks ($\frac{Q}{N^V * Q^V}$ = 0,57). For type B, the VLM area of application is for values of Q^*/Q^V higher than about 65%, for the storage volume V^V of 75 m^3. Here, the condition $\frac{Q}{N^V * Q^V} > \frac{Q^*}{Q^V}$ is verified, since $\frac{Q}{N^V * Q^V}$ = 0.866.

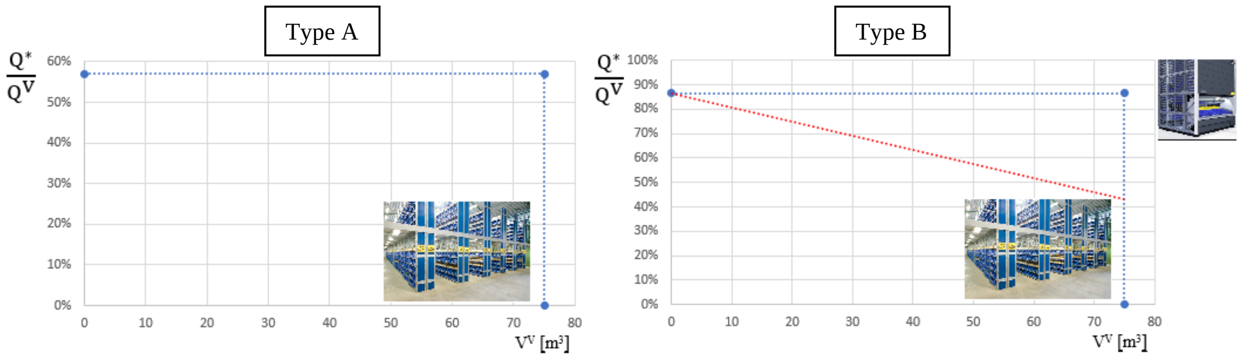

Fig. 3. „Trend of $\frac{Q^*}{Q^V}$ and VLM area of application for the analyzed cases" [6, 8, 9, 10].

- Total costs and saving calculation

For type B, the applicability of the VLM system can be demonstrated also by calculating the total cost functions of the two alternatives. For the as-is scenario of the warehouse with R3000 racks, the total cost is :

$$TC^W = C_{SP} * k^W * \frac{V}{SL^W * H} + C_{OP} * \frac{Q}{Q^W} * h_y = 23.310 + 155.925 = 179.235 \text{ €/year} \quad (4)$$

Based on the input data, the required number of VLMs to be installed N^V is :

$$N^V = \max\left(\left\lceil\frac{Q}{Q^V}\right\rceil; \left\lceil\frac{V}{V^V}\right\rceil\right) = \max\left(\left\lceil\frac{360}{138}\right\rceil; \left\lceil\frac{180}{75}\right\rceil\right) = 3 \quad (5)$$

and the total cost can be estimated as such:

$$TC^{V} = N^{V} * \left[\left(C_{SP} * k^{V} * \frac{V^{V}}{SL^{V} * H} \right) + C_{OP} * \frac{Q}{N^{V} * Q^{V}} * h_{y} \right] = 3 * 5.512,5 + 109.200 = 125.737,5 \text{ €/year} \quad (6)$$

The total savings obtained by installing the VLM system is approx. € 53,500/year, so approx. 29.8%. It is to be noted that the structure of the model analyzed above is taken from the reference [6].

The simulation of such an example of picking system efficiency is presented in the following video:

Simulation_SCSS.mp4

Video no.1 - Parallel simulation of picking systems [11]

4. Conclusions

In the process of supplying and orders fulfilling in the logistics system, it is important to develop picking. Thanks to innovation, the work is easier for the operators, but the process is also more efficient: better times, more order lines/h, flow with fewer interruptions in the supply chain, more space in warehouses, more storage capacity, etc.

The trend is developing for the transition, at least, from standard systems to semi-automated picking systems, which creates the wave effect, as an improvement, in the supply chain.

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6. Notations

Notations

Symbol	Significance
Q [picks/h]	Required flow/hour $Q = \sum_{i=1}^{n} Q_i$
N [lines/order]	Average number of lines on the picking order
V [m^3]	Total storage volume $V = \sum_{i=1}^{n} V_i$
H [m]	Available height
C_{SP} [€/(hm^2)]	Annual cost of space per square meter
C_{OP} [€/h]	Hourly operating cost
h_y [h]	Number of working hours in a year
TC^S [€/an]	The total cost of the annual order picking system, s ϵ {W, V}
C_{fix}^S [€/an]	The fixed cost of the annual order picking system, s ϵ {W, V}
C_{var}^S [€/an]	The variable cost of the annual order picking system, s ϵ {W, V}
k^s	Cost coefficient of the order picking system space, s ϵ {W, V}
SL^s	Saturation level of the control lift system, s ϵ {W, V}
Q^s [picks/h]	Flow / hour of the control lifting system, $Q^s = 3{,}600/t_l^s$, s ϵ {W, V}
t_l^s [s]	Average cycle time per line, s ϵ {W, V}
t_{pick}^s[s]	Picking time, s ϵ {W, V}
t_{fix}^s [s]	Time for fixed activities, s ϵ {W, V}
t_{travel}^s [s]	Travel time, s ϵ {W, V}
A^W [m^2]	The area of the surface where the mezzanine is located
N^V	Number of VLMs
V^V [m^3]	The storage capacity as volume of a VLM
R_Q	Systems flow ratio
SBS/RS	Transfer-based storage and retrieval system
VLM	Vertical Lift Module
AS/RS	Automatic storage and recovery system