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# ERGONOMIC ASSESSMENT OF PICKING FROM CAROUSELS USING OCRA INDEX

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***Abstract:*** *In this paper application of OCRA index risk assessment method for order-picking processes using carousels is presented. Analysis included both vertical and horizontals carousels, as well as picking from single devices and from systems of a few devices in pods, based on two different cases regarding picking productivity. The results show that there are no significant risks in cases with lighter items and less intensive picking, but there may be a significant risk for heavier items and more intensive work.*
***Key words:*** *order-picking, horizontal carousel, vertical carousel, ergonomic assessment, OCRA index*

## 1. INTRODUCTION

Warehouses are constantly under pressure for more efficient and effective performances. In order to achieve this, managers have recently been using different methods and concepts, from the organizational aspects to the more automated and robotized operations. However, with people involved in processes, one must consider as well human factors, ensuring job demands do not exceed worker's capabilities. This is a responsibility of ergonomics.

The most labor-intensive and time-consuming activities in warehouse are those from manual order picking [1], accounting for more than 50% of warehouse operating costs [2, 3]. This process is usually an important goal in improving warehouse operations. One way of improvement is with using appropriate operating methods (like routing, storage or order-picking methods) in usual manual order-picking "picker-to-part" systems. In those systems, usually with a classical shelf or pallet racks, humans are routed with picking lists to storage locations to retrieve items for customers' orders. Another way to improve order-picking operations is to change the system itself, using some form of automated storage and retrieval systems (AS/RSs) to facilitate the picking process. Whether it is a mini-load AS/RS, shuttle-based storage and retrieval system (SB-S/RS), carousels or vertical lift modules (VLMs), in those systems, items are brought to the pickers naming it "part-to-picker" systems. Of course, the primary objective of using those systems are productivity and space efficiency gains. Additionally, having people not walking from location to location and reaching and/or bending to pick items from upper/lower shelf levels or positions on a pallet, a secondary objective in better ergonomics is also achieved. However, increasing productivity definitely reduces short breaks between picks and increases the frequency of repetitive object-grabbing tasks. Such intense high-productive picking might be cause of fatigue. Even if heavy loads are not picked, in which case there is no visible excessive strain, a high frequency of repetitive tasks of picking smaller items in a high productive order-picking system might as well be too demanding.

Ergonomics/human factors are a topic of concern in logistics, namely manual material handling, for many years. Plenty of research papers were written, with guidelines [4] and principles [5] recommended. However, ergonomics of order-picking was not so much in the focus of researchers. Only in last decade we can witness increased interest for human factors in order-picking, being put into the framework of research by Grosse et al. [6]. Particular research papers were mainly on ergonomics in manual order-picking systems, focusing on storage assignment methods that include both order-picking time and health risk/human energy expenditure. Only two conference papers deal with the ergonomic assessment of order-picking using "part-to-picker" systems, for picking from VLM [7] and for picking from single horizontal carousel [8] devices, in comparison with picking from shelving "picker-to-part" system. Those papers used a prediction method for human energy expenditure based on physiological measurements. Assessment of the picking process from such systems using risk assessment methods is lacking, although producers and promoters of such systems will regularly advocate those systems for the ergonomic advantages (in comparison with the classical picking systems).

This paper attempts to evaluate the risk of picking from two devices facilitating "part to picker" systems, namely horizontal and vertical carousels. Those devices might be used as single machines, where picking is only slightly improved, or as a system of a few devices (called a pod) with extremely high picking productivity. OCRA index method to calculate risk was used. OCRA index is a method to analyze workers' exposure to tasks featuring various upper-limb injury risk factors, proposed by the ISO 11228. Because the human operator is standing in a fixed place and items are picked by habds, the idea of this research is to focus on the upper part of the body considering repetitiveness (picking item by item of plenty orders), force (in some cases items or storage bins might be with higher masses to be pulled and/or lifted), awkward postures and movements (grasping items with the hand) and lack of recovery periods (very high productive picking without waiting/resting periods).

## 2. ERGONOMICS / HUMAN FACTORS FOR ORDER-PICKING

Various processes are carried out under the roof of warehouses and distribution centers, and the most expensive is order-picking. Although order-picking attracts attention primarily because of the costs, it is increasingly at the forefront also because of the intensity of human labor. Order-pickers are often lower-paid workers who are becoming increasingly difficult to obtain. The work does not require special education but only strength, agility and perseverance. The work is technologically undemanding but involves a high frequency of repetition of a narrow set of movements lifting and lowering loads, and torsional rotations of the body. The aging of the population is in no way to the advantage of employers, nor is it raising the level of education. Young people want flexible, sliding working hours, which contrasts with the multi-shift work of order-pickers. As a result, workers inadvertently come to the forefront of employers' attention. Employers are particularly drawn to absenteeism, which averages 10% in the European Union [9]. These trends and ways of thinking are reflected in the two researched streams in order-picking, time, and ergonomics optimizations, which have recently overlapped or complemented each other.

The most scientific contributions are on time optimization. The shipment preparation time depends on order-picking environment arrangements (workplace's factors) and order-picker's characteristics (worker's factors). Workplace's factors can be further divided into subgroups:

- Picking condition (automation equipment, shelf height, ambient temperature, need to walk between storage locations, lighting, type of goods identification);
- Travel distance (routing method);
- Weight of goods;
- Grip quality (the presence of holders, surface roughness, shape stability);
- Number of orders per shift.

Worker's factors can be further divided into subgroups:

- health condition (recovering from musculoskeletal disses);
- Age;
- Gender;
- Training (healthy work, planned implementation of movements);

- Personal habits (exaggeration, denial of pain, overexertion);
- Anthropometrics.

However, these factors do not only affect the timing of operations, they also affect energy expenditure and risk for musculoskeletal disorders (MSD) [10]. Time optimization results in more picks per time unit and, consequently, increased energy expenditure and risk for MSD because of more frequent movements. Any time optimization thus requires consideration of its impact on a worker from the point of view of ergonomics. The importance of the ergonomic dimension is also growing due to its connection with ethics [11-13] and social sustainability [14]. Any change in the order-picking workplace requires an ergonomic risk assessment for the worker, in addition to time conversion, based on worker's personal characteristics. No postures should represent a high health risk for MSDs occurrence.

As already said in the introduction, in order-picking, we distinguish between two approaches, namely "picker-to-part" and "part-to-picker". In "part-to-picker"systems, pickers are involved in intensive walking between picking locations and picking from various heights of racks, so those systems also received more attention regarding time optimization and ergonomics. The optimization result was the assignment of order-picking units at storage locations most often. Recently, energy expenditure calculation was added to time optimization in bi-objective modelling for storage assignments in shelf racking system by Battini et al. [15].

Similar decisions were researched for the fast-pick area by Otto et al. [16]. Order picking time, energy expenditure, and health risk are evaluated in optimization models by Calzavara et al. [17, 18]. Rest allowance estimation based on energy expenditure for picking was presented in Calzavara et al. [19]. Larco et al. [20] researched trade-off analysis between time-based and ergonomics-based functions, while many other researches [12-16] proved that the mass of the unit in the order-picking process, the height for lifting, and the height for lowering effect order-picking operations' times significantly [13].

Less research is done on ergonomics in "part-to-picker" order-picking systems. However, many of the findings from the picker-to-part" research stream also apply to the "part-to-picker". In many cases, "part-to-picker"systems involve some kind of automation for bringing items (totes, bins, trays) to the picker. However, the retrieval of items is done manually by the picker. Therefore, again some grabbing, lifting, lowering and/or pulling masses are involved, posing certain risks for MSD. On the other hand, implementation of those picking systems usually involves increased productivity, imposing workers with much more intense work in terms of picking repetitions. As said, only two conference papers deal with the ergonomic assessment of order-picking using "part-to-picker" systems.

Dukic et al. [7] also included ergonomic evaluation in space, time, and ergonomic assessment of VLM, while Dukic et al. [8] provided a similar assessment for picking from a single horizontal carousel. Both papers based ergonomic evaluation on metabolic energy expenditure method (as used in [15, 17, 18] and [19], originally presented in Garg et al. [21] (similar ideas have been debated by [10-13].

## 3. HORIZONTAL AND VERTICAL CAROUSELS

Carousels are devices that have long history since the 1950s. Since the late 1990s, carousels have been placed under the more general category of AS/RS, being nowadays an important part of the automated storage and retrieval systems' family [22-24].

According to the definition given by MHI, a horizontal carousel (HC) is a storage device that consists of a fixed number of adjacent storage columns or bays that are mechanically linked to either an overhead or floor-mounted drive mechanism to form a complete loop. Each column is divided into a fixed number of storage locations or bins, which in most applications are constructed of a welded wireframe (as illustrated in Figure 1 [22]).

Loads consisting of containers or totes may be inserted and retrieved manually or by an automatic inserter/extractor mechanism.

However, the carousel rotation in a horizontal loop is almost always controlled automatically [22].

**Fig. 1.** Stand-alone horizontal carousel unit [22].

**Fig. 2.** Two horizontal carousel units in pod [24].

The first applications of single carousel units were primarily in manufacturing environments for storage. While still used as single machines, horizontal carousels are now used as components of distribution systems for order-picking operations [23]. With the primary purpose of achieving high picking productivity, several horizontal carousels are creating a pod-integrated work center configuration of 2, 3 or even 4 horizontal carousels (units) per operator (human picker), as illustrated in Figure 2 as one example.

There are numerous benefits of using carousels. Even using one device as a stand-alone machine enables some time benefits because parts are brought to the operator instead of the need to walk to the parts. Operators then might spend time on other work (paperwork, counting, etc.) while waiting for the next part. In pods waiting time (wasted time) is further reduced or eliminated because while the operator is picking items from one carousel, other(s) are already rotating and preparing the following locations. In that way, high picking productivity is achieved. While retrieval is at the face of the device, there is no need for aisles on the sides of carousels, saving valuable space. Better storage space usage is also achieved with better storage density, resulting from the minimal spacing needed between storage bins. Computerized control improves inventory management and improves accuracy. Accessing carousels only at the front ensures better security of stored items and increases supervising control of workers. And finally, the most important thing for analysis in this paper, the elimination of walking might reduce the operator's fatigue and boredom. However, as said in the introduction, higher productivity in pod systems might, despite eliminating walking, increase fatigue due to more frequent picking.

Vertical carousels (VC), as the name suggests, are devices where locations are rotating in a vertical loop. Similarly, MHI defines it as a device that provides for a closed loop automatically controlled rotation of the basic storage unit, which in this case may be a shelf that can be subdivided into multiple bin locations (as illustrated in Figure 3). Although automatic insertion and extraction of individual items or loads is possible, it is not as common as it is with horizontal carousel applications [22].

**Fig. 3.** Vertical carousel unit [24].

Benefits of using vertical carousels are also numerous and similar to benefits of horizontal carousels. The biggest difference is obvious, using available space in vertical dimension, vertical carousels offer a significant reduction of floor storage space. Since the items are delivered directly to the operator, a significant reduction in search time is realized, making vertical carousels a good solution for picking operations. Although vertical carousels are mainly used in practice as single machines, one can also combine several vertical carousels in a pod for increased picking productivity, just as horizontal carousels (illustrated in Figure 4). Every vertical carousel can be supplied as a completely enclosed, six-sided cabinet, offering extremely effective security for valuable items, as well as a clean and safe storage location [25].

Improved inventory management and accuracy of operations are similar to horizontal carousels. And again, for this paper most important ergonomics is highlighted. Not only with eliminated walking (therefore reduced related fatigue), better ergonomics is achieved by bringing items to the most ergonomic level for handling (waist level, so called golden zone). A vertical carousel almost completely eliminates the need to reach, bend or climb, which reduces potential employee injury-related costs while, at the same time, productivity and accuracy increase (less time to pick items from the most ergonomic position, potential avoidance of productivity loss and increased errors due to the worker's fatigue) [13-16].

## 4. OCRA INDEX CALCULATION FOR PICKING FROM CAROUSELS

The ergonomic assessment method used for the evaluation of order-picking tasks with carousels was OCRA index. OCRA, or in full name Occupational Repetitive Actions, are methods developed by Occhipinti and Colombini in 1996 [26] to analyze workers' exposure to tasks featuring various upper-limb injury risk factors (repetitiveness, force, awkward postures and movements, lack of recovery periods, and others, defined as "additionals"), consisting of two methods – OCRA index and OCRA checklist. The OCRA index is a method of risk prediction of upper extremity work-related musculoskeletal disorders (WMSDs) in exposed populations and is generally used for deep, more detailed analysis of workstations and tasks.

The OCRA checklist is simpler, although also based on the OCRA index, generally recommended for the initial screening of workstations featuring repetitive tasks. OCRA methods are nowadays part of the two technical standards. In EN 1005-5 OCRA is a method of choice, while in ISO 11228-3 OCRA index is preferred method for detailed risk assessment because it considers all the relevant risk factors.

The selection of the OCRA index method for ergonomic commissioning analysis was based on the fact that this method considers many relevant risk factors for the upper limb. Relevant risks for this study were repetitiveness and lack of recovery periods for high productive picking productivity in a "part to picker" system, with the possibility to analyze work with different forces (related to the mass of the picked items) and postures (picking from the upper locations of horizontal carousel).

The limitation of this method is that it does not include walking, turning, lifting and lowering loads, torso rotation, which might also be a part of the work described in a picking station. However, it was assumed that two risk factors are insignificant and are not covered in the analysis based on the OCRA method. The first refers to putting items on the conveyor or in a container placed on a table or a vehicle after picking them up from the carousel's rotation. The second is walking with possible turnaround between carousels in pods.

The analysis was done for two distinct situations (analyzed in the diploma thesis [27]).

The first assumed picking from a single carousel, horizontal or vertical, where the usual picking rate is 100-150 picks per hour. For analysis, we selected a total number of picks per shift equals 1000 (which corresponds to the approximately 143 picks per hour in a 7-hour work per shift).

The second situation assumed picking from a highly productive picking system of several carousels in a pod, where picking rates might go even over 500 picks per hour. In this case, intensive work of extreme 4000 picks per shift was selected (or approximately 571 picks per hour).

Net working time was therefore seven hours. OCRA index is calculated as a rate between the number of technical actions actually carried out during the work shift (actual technical actions, ATA), and the number of technical actions which is specifically recommended (recommended technical actions, RTA).

Consequencily, to calculate OCRA indexes for above cases, number of recommended technical actions $n_{RTA}$ should be calculated, using equation with multiplier factors $F_M$, $P_M$, $R_{eM}$, $A_M$, $R_{cM}$, constant of frequency of technical action $k_f$=30, net duration of each repetitive task $t_j$ and duration multiplier factor $t_M$.

$$n_{RTA} = \sum_{j=1}^{n}\left[k_f\left(F_{Mj} \times P_{Mj} \times R_{eMj} \times A_{Mj}\right) \times t_j\right] \times (R_{cM} \times t_M). \quad (1)$$

In this article (and the presented research), detailed explanations of the parameters and guidelines on their selection are avoided due to the limited size of the paper, and can be found in other sources on the OCRA index method. For understanding the differences and scope of the analysis, only important parts such as risk factors are presented.

For the force multiplier factor (FM) for each repetitive task, analysis was done for all possible values in a method (1, 0.85, 0.65, 0,35, 0.2 and 0.01) representing scores of Borg Rating of Perceived Exertion Scale (CR-10) from very weak (small, light items to be picked) to very strong (bigger, heavier items to be picked by hand(s)).

Picking from a vertical carousel was assumed to be the job of two tasks – pulling the tote from the shelf and then item retrieval from the tote. Picking from a horizontal carousel has only one task – retrieval from the delivered bin. The total time to pick an item from both carousels was kept the same for analysis.

For the postural multiplier factor (PM) for each repetitive task, it was assumed that pulling the tote in a vertical carousel is from the ideal position (postural factor is 1) while retrieval requires a hand grip therefore factor is 0.6. Picking from two higher levels of horizontal carousels causes additional shoulder flexions, therefore changing postural factors to 0.5 and 0.33, respectively.

Assumptions regarding times were as follows. The total time of one pick was assumed 4 seconds (with 25% for tote pulling and 75% of item retrieval from tote in vertical carousels, and 100% for item retrieval from the bin in horizontal carousels, respectively). Net times of work were assumed based on a total number of picks per shift and (picking time per item is 4 seconds), leading to the values of net duration of each task t.

The repetitiveness multiplier factor ($R_{eM}$) for both tasks in a single vertical carousel and a single horizontal carousel is 1 because the cycle is longer than 15 seconds (1000 cycles per shift in 7 hours). However, for picking from pods, due to the high productivity and cycle time of less than 8 seconds (4000 cycles per shift in 7 hours), the repetitiveness factor is 0,7.

The additional multiplier factor ($A_M$) is 1 in all situations (there are no additional conditions influencing tasks).

The recovery multiplier factor ($R_{cM}$) is 1 for picking from single carousels (because of more than 20 seconds waiting time for the next pick), while 3 for picking from pods (no short pauses, one 30 minutes break with 3 small 10 minutes break during entire 480 minutes shift were assumed). The duration multiplier factor ($t_M$) is 1 (work in one shift, net time 7 hours).

The calculated OCRA index is then classified according to Table 1.

*Table 1*

**Classification of the OCRA index.**

| Area | OCRA indeks values | Risk classification |
|---|---|---|
| Green | ≤ 1,5 | Optimal |
| Gree-Yellow | 1,6 - 2,2 | Acceptable |
| Yellow-Red | 2,3 - 3,5 | Uncertain or very low |
| Red-light | 3,6 - 4,5 | Light |
| Red-medium | 4,6 - 9 | Medium |
| Red-high | ≥ 9,1 | High |

## 4.1 OCRA indexes for picking from stand-alone carousels

In Table 2 and Table 3 results of recommended number of technical actions of pulling the tote and retrieving the item from vertical carousel are presented, respectively. As said, values are calculated for range of different force multiplier factors representing perceived exertion (which would result from the mass of pulled and grabbed/lifted tote and items).

Total number of recommended actions of picking from the vertical carousel would depend on the sum of values for appropriate tasks. For theoretical analysis and further comparison with horizontal carousels, if we assume the same perceived exertion for pulling the tote and retrieving the item, the total number of recommended technical actions for vertical carousels is shown in Table 4.

*Table 2*

**Recommended number of technical actions $n_{RTA1}$.**

| Single Vertical Carousel - tote pulling (25% of picking time) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $k_f$ | $F_{M1}$ | $P_{M1}$ | $R_{eM}$ | $A_M$ | $t_1$ | $R_{cM}$ | $t_M$ | $n_{RTA1}$ |
| 30 | 1 | 1 | 1 | 1 | 16,67 | 1 | 1 | 500,10 |
| 30 | 0,85 | 1 | 1 | 1 | 16,67 | 1 | 1 | 425,09 |
| 30 | 0,65 | 1 | 1 | 1 | 16,67 | 1 | 1 | 325,07 |
| 30 | 0,35 | 1 | 1 | 1 | 16,67 | 1 | 1 | 175,04 |
| 30 | 0,2 | 1 | 1 | 1 | 16,67 | 1 | 1 | 100,02 |
| 30 | 0,01 | 1 | 1 | 1 | 16,67 | 1 | 1 | 5,00 |

*Table 3*

**Recommended number of technical actions $n_{RTA1}$.**

| Single Vertical Carousel - item retrieval (75% of picking time) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $k_f$ | $F_{M1}$ | $P_{M1}$ | $R_{eM}$ | $A_M$ | $t_1$ | $R_{cM}$ | $t_M$ | $n_{RTA1}$ |
| 30 | 1 | 1 | 1 | 1 | 50 | 1 | 1 | 1500,00 |
| 30 | 0,85 | 1 | 1 | 1 | 50 | 1 | 1 | 1275,00 |
| 30 | 0,65 | 1 | 1 | 1 | 50 | 1 | 1 | 975,00 |
| 30 | 0,35 | 1 | 1 | 1 | 50 | 1 | 1 | 525,00 |
| 30 | 0,2 | 1 | 1 | 1 | 50 | 1 | 1 | 300,00 |
| 30 | 0,01 | 1 | 1 | 1 | 50 | 1 | 1 | 15,00 |

*Table 4*

**OCRA index for vertical carousel.**

| Single Vertical Carousel | | | | | |
|---|---|---|---|---|---|
| $F_{Mj}$ | $n_{RTA1}$ | $n_{RTA2}$ | $\sum n_{RTAj}$ | $n_{ATA}$ | *OCRA indeks* |
| 1 | 500,10 | 1500,00 | 2000,10 | 1000 | 0,50 |
| 0,85 | 425,09 | 1275,00 | 1700,09 | 1000 | 0,59 |
| 0,65 | 325,07 | 975,00 | 1300,07 | 1000 | 0,77 |
| 0,35 | 175,04 | 525,00 | 700,04 | 1000 | 1,43 |
| 0,2 | 100,02 | 300,00 | 400,02 | 1000 | 2,50 |
| 0,01 | 5,00 | 15,00 | 20,00 | 1000 | 50,00 |

Table 5 presents the recommended number of technical actions for picking from a single horizontal carousel. There is only one task, retrieval of items from the bins, in this case. However, picking from different levels of horizontal carousels are different actions regarding position factor.

*Table 5*

**Recommended number of technical actions $n_{RTAj}$.**

| Single Horizontal Carousel | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Level 1 (bottom) | | | | | | | | |
| $k_f$ | $F_{M1}$ | $P_{M1}$ | $R_{eM}$ | $A_M$ | $t_1$ | $R_{cM}$ | $t_M$ | $n_{RTA1}$ |
| 30 | 1 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 1200,06 |
| 30 | 0,85 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 1020,05 |
| 30 | 0,65 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 780,04 |
| 30 | 0,35 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 420,02 |
| 30 | 0,2 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 240,01 |
| 30 | 0,01 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 12,00 |
| Level 2 | | | | | | | | |
| $k_f$ | $F_{M1}$ | $P_{M1}$ | $R_{eM}$ | $A_M$ | $t_1$ | $R_{cM}$ | $t_M$ | $n_{RTA1}$ |
| 30 | 1 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 1200,06 |
| 30 | 0,85 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 1020,05 |
| 30 | 0,65 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 780,04 |
| 30 | 0,35 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 420,02 |
| 30 | 0,2 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 240,01 |
| 30 | 0,01 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 12,00 |
| Level 3 | | | | | | | | |
| $k_f$ | $F_{M1}$ | $P_{M1}$ | $R_{eM}$ | $A_M$ | $t_1$ | $R_{cM}$ | $t_M$ | $n_{RTA1}$ |
| 30 | 1 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 1200,06 |
| 30 | 0,85 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 1020,05 |
| 30 | 0,65 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 780,04 |
| 30 | 0,35 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 420,02 |
| 30 | 0,2 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 240,01 |
| 30 | 0,01 | 0,6 | 1 | 1 | 66,67 | 1 | 1 | 12,00 |
| Level 4 | | | | | | | | |
| $k_f$ | $F_{M1}$ | $P_{M1}$ | $R_{eM}$ | $A_M$ | $t_1$ | $R_{cM}$ | $t_M$ | $n_{RTA1}$ |
| 30 | 1 | 0,5 | 1 | 1 | 66,67 | 1 | 1 | 1000,05 |
| 30 | 0,85 | 0,5 | 1 | 1 | 66,67 | 1 | 1 | 850,04 |
| 30 | 0,65 | 0,5 | 1 | 1 | 66,67 | 1 | 1 | 650,03 |
| 30 | 0,35 | 0,5 | 1 | 1 | 66,67 | 1 | 1 | 350,02 |
| 30 | 0,2 | 0,5 | 1 | 1 | 66,67 | 1 | 1 | 200,01 |
| 30 | 0,01 | 0,5 | 1 | 1 | 66,67 | 1 | 1 | 10,00 |
| Level 5 (top) | | | | | | | | |
| $k_f$ | $F_{M1}$ | $P_{M1}$ | $R_{eM}$ | $A_M$ | $t_1$ | $R_{cM}$ | $t_M$ | $n_{RTA1}$ |
| 30 | 1 | 0,33 | 1 | 1 | 66,67 | 1 | 1 | 660,03 |
| 30 | 0,85 | 0,33 | 1 | 1 | 66,67 | 1 | 1 | 561,03 |
| 30 | 0,65 | 0,33 | 1 | 1 | 66,67 | 1 | 1 | 429,02 |
| 30 | 0,35 | 0,33 | 1 | 1 | 66,67 | 1 | 1 | 231,01 |
| 30 | 0,2 | 0,33 | 1 | 1 | 66,67 | 1 | 1 | 132,01 |
| 30 | 0,01 | 0,33 | 1 | 1 | 66,67 | 1 | 1 | 6,60 |

Table 6 shows the corresponding OCRA index, again for various factors representing perceived exertion of item retrievals, averaged for picking from all 5 levels equally.

Results show that for picking from the single carousel, both vertical and horizontal, risks are mostly optimal or acceptable except in situations where strong and very strong exertion is perceived. Although situations where heavy items are stored and picked from carousels (like some molds, castings, heavy tools and devices, etc.), it is not common for such items to be stored in carousels for higher productivity picking purposes.

Comparison of results also shows that vertical carousels are with slightly lower indexes, which is expected and logical due to the picking from also higher locations using horizontal carousel, while vertical carousel has optimal pick position (the difference is important in a situation where moderate or strong exertion is perceived).

*Table 6*

**OCRA index for horizontal carousel.**

| Single Horizontal Carousel | | | |
|---|---|---|---|
| $F_{Mj}$ | $\sum n_{RTAj}$ | $n_{ATA}$ | OCRA indeks |
| 1 | 1052,05 | 1000 | 0,95 |
| 0,85 | 894,24 | 1000 | 1,12 |
| 0,65 | 683,83 | 1000 | 1,46 |
| 0,35 | 368,22 | 1000 | 2,72 |
| 0,2 | 210,41 | 1000 | 4,75 |
| 0,01 | 10,52 | 1000 | 95,05 |

## 4.2 OCRA indexes for picking from carousel pods

Similar calculations were done for picking from carousels' pods. In this case number of cycles is much higher (4000 per shift), leading to the different repetitiveness factor (RcM=0.7 in all cases), recovery factor (ReM=0.7 in all cases) and duration times of actions (t1=66,67 minutes for tote pulling in vertical carousels, t2=200 minutes for item retrieval from a vertical carousel, and t=266,67 minutes for item retrieval from horizontal carousels. The difference between the sum of picking times of all 4000 cycles and the total net time is assumed to be time for movement between carousels in pods. Table 7 and Table 8 present the final results with calculated OCRA indexes.

Again, as expected, picking from vertical carousels pod has slightly lower risks than picking from horizontal carousels pod, for the same values of perceived exertions. The reason is the same as for single units, picking some items from higher levels. Comparing results for pods with results for single devices, it is obvious that highly intensive picking without resting between picks might lead to increased risks for MSD for moderate exertions for picking from vertical carousels and even for weak exertions for picking from horizontal carousels. Of course, it is again a theoretical finding, while in practice is unlikely that a high productivity system of carousels in pod would be used for picking heavier items where perceived exertion of such tasks would be considered as moderate, strong or very strong.

*Table 7*

**OCRA index for vertical carousels in pod.**

| Vertical Carousels pod | | | | | |
|---|---|---|---|---|---|
| $F_{Mj}$ | $n_{RTA1}$ | $n_{RTA2}$ | $\sum n_{RTAj}$ | $n_{ATA}$ | OCRA indeks |
| 1 | 980,05 | 2940,00 | 3920,05 | 4000 | 1,02 |
| 0,85 | 833,04 | 2499,00 | 3332,04 | 4000 | 1,20 |
| 0,65 | 637,03 | 1911,00 | 2548,03 | 4000 | 1,57 |
| 0,35 | 343,02 | 1029,00 | 1372,02 | 4000 | 2,92 |
| 0,2 | 196,01 | 588,00 | 784,01 | 4000 | 5,10 |
| 0,01 | 9,80 | 29,40 | 39,20 | 4000 | 102,04 |

*Table 8*

**OCRA index for horizontal carousels in pod.**

| Horizontal Carousels pod | | | |
|---|---|---|---|
| $F_{Mj}$ | $\sum n_{RTAj}$ | $n_{ATA}$ | OCRA indeks |
| 1 | 2061,95 | 4000 | 1,94 |
| 0,85 | 1752,65 | 4000 | 2,28 |
| 0,65 | 1340,26 | 4000 | 2,98 |
| 0,35 | 721,68 | 4000 | 5,54 |
| 0,2 | 412,39 | 4000 | 9,70 |
| 0,01 | 20,62 | 4000 | 193,99 |

## 5. CONCLUSION

This paper uses the OCRA index method to evaluate order-picking processes from vertical and horizontal carousels. Based on two cases of application that might appear in practice – a single carousel or few carousels in a pod, OCRA indexes were calculated based on assumed multiplier factors and times of tasks.

Results show differences between vertical and horizontal carousels, being vertical more favorable. This is expected due to the fact that one should use risky shoulder flexions for picking items from top levels of horizontal carousels. Also, results show higher risks for picking items from pods. This is as well expected due to the high intensity of picking without resting time between picks. However, picking small, light items would be still with optimal or acceptable risk. Picking heavier items would be risky, however, it is unlikely one would use those systems for high picking rates of heavy items.

OCRA index method, intended for risk assessment of upper-limb injuries, was selected for analysis because carousels are order-picking systems where parts are brought to the picker. Pickers are picking while standing or sitting. Pickers are simply waiting between picks for the next item (in case of single carousels) or slightly moving/turning around for the next item to be picked (in case of pods). Therefore, actions of slight walking between carousels, turning around, possibly twisting torso for putting items on cart, conveyor or sortation tote, as well as bending for picking from lower positions in horizontal carousels are not covered with this method. Nevertheless, this attempt to assess the ergonomics of order-picking from carousels might motivate further analysis with different methods.

In further research other ergonomic methods for risk assessment will be used, in order to compare different methods and find most suitable method for ergonomic risk analysis of "picker to part" order-picking systems. Ergonomic assessment using metabolic energy expenditure method will be also used for identical cases as in this paper, in order to evaluate possible correlation between risks and energy expenditure (fatique). This might include some research in practice (real cases), to link subjective feeling regarding perceived extersion in OCRA index with actual mass of picked items needed for energy expenditure calculation. Research in practice is also desireable to get real numbers of picking productivity in relation with the masses, as well as influence of possible different assignment rules for items (for instance heavier items in middle levels of horizontal carousels, more popular items in middle levels of horizontal carousels).

The practical implications of the presented research are aligned with those presented by [28, 29]. Future studies, extended researches should considered the international tendencies and new approaches developed by [30].

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## Evaluarea ergonomică a ridicării din carusele folosind indicele OCRA

**Rezumat:** În această lucrare este prezentată aplicarea metodei de evaluare a riscului pe baza determinării indicelui OCRA, în cazul proceselor de ridicare relative la comenzile caruselelor din sisteme logistice. Analiza a inclus atât carusele verticale, cât și orizontale, precum și ridicarea de pe dispozitive individuale și din sisteme de câteva dispozitive suprapuse, bazate pe două cazuri diferite privind productivitatea ridicării. Rezultatele arată că nu există riscuri semnificative în cazul manipulării unor articole mai ușoare și ridicări mai puțin intensive; cu toate acestea, pentru articole mai mari, pot apărea riscuri de muncă severe.

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