HUMAN IN MANUAL ORDER PICKING SYSTEMS

Brigita GAJŠEK[1], Goran ĐUKIĆ[2], Tihomir OPETUK[2], Hrvoje CAJNER[2]

[1]University of Maribor, Faculty of Logistics
Mariborska cesta 7, Celje, Slovenia

[2]University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture
Ivana Lučića 5, Zagreb, Croatia

Abstract

A key priority of the Europe 2020 is to create more and better jobs, while improving their quality and ensuring better working conditions. Manual order picking is an example of labour-intensive and time-consuming working environment where humans are central actors and determine their effectiveness and efficiency. Researchers have developed models for increasing the efficiencies of such systems by suggesting different methods and approaches but largely ignore workers' characteristics, suggesting that they cannot be substantiated, which led to partially realistic results. Authors determine with scientific literature review the current state of research and the possibilities of interdisciplinary synergies to optimise human productivity by taking into account human's capabilities.

Keywords: picker-to-parts, order picking, ergonomics, productivity, human factors

1. INTRODUCTION

A key priority of the European Union's employment strategy and Europe 2020 is to create more and better jobs in Europe, while improving their quality and ensuring better working conditions [1]. Future development is planned and financially supported on the assumption that improvement of working conditions can ensure a longer working life and more sustainable work and employment. It is frequently written that in order to achieve economic growth and job creation, the working conditions of all workers need to be improved through higher standards of occupational health, safety and well-being at work, as well as enhanced opportunities for skills development and employment prospects. Mentioned changes will have positive effects on participation in the labour market and on company productivity. Consequently, changes will reduce the risk of absenteeism and healthcare costs and improve family and social life.

Order picking is the process of retrieving items from their storage locations in a warehouse to fulfil customers' orders [2]. Its activities are labour-intensive and time-consuming, and they account for more than 50% of warehouse operating costs [3,4]. Order picking is the most expensive warehouse operation and it is directly linked to customer satisfaction. Any wrong pick would lead to an unhappy customer and additional costs. According to De Koster, Le-Duc, and Roodbergen [5] more than 80% of all orders processed by warehouses are picked manually, which has been also confirmed in a recent study [6]. Despite automation and robotisation of warehouse processes, large share of all orders will still remain picked manually also in near future.

Above facts suggest that manual order picking is intensively researched from several perspectives, for example technical, organizational, ergonomics and other. Studies have shown that the most frequently mentioned and requested performance and efficiency of the order picking operation depend mainly on the demand pattern, the configuration (layout) of the warehouse, the storage strategy, the batching method, the routing and sorting method [7,8]. It is much less frequently mentioned that manual order picking system performance depend also on product characteristics, human characteristics, storage equipment design, forklifts' characteristics and information technology used.

An indisputable fact is that human is the main performer of order picking process, who enters in the process by his/her unique combination of physical and personality characteristics. This demands reconsideration of research findings in the field of manual order picking. Researchers like Grosse and Glock [9] have recently started to consider that human as such always affect the successful implementation of proven mathematically optimal policies and layouts. The alike was previously also observed by some others. Although, in order to reduce total picking time, academics proposed very complex batching techniques with near optimal results that consider both order size and product volumes [11], they were quickly dismissed by the subject firm because the logic for these batching methods are difficult to convey to the employees [12].

Another important issue reducing productivity and prolonging order retrieval time in manual order picking is worker's fatigue, which additionally has increasingly been viewed by society as a safety hazard [10]. Fatigue is not just a result from not enough sleep but also because of worker's individual characteristics, work type or organization and the working environment. For example, manual carrying and lifting of large, bulky and/or heavy objects can cause musculoskeletal injuries. They can be caused also by long-lasting repetitive work movements and awkward postures which are common in order picking process. Maintaining the same posture for extended periods causes excessive fatigue. Repetitive work, tasks with little variety and/or few events and confusing and/or missing information may lead to boredom and errors being made. Too high physical load may also cause excessive fatigue, especially in a hot environment. Musculoskeletal disorders (MSD) are the most reported causes for absence from work and account for over 52% of all work-related illnesses and more than 2% of the gross national product in the European Union [13], where low back disorders are the costliest of the musculoskeletal disorders [14]. For this reason and in light of demographic changes and an increasing work lifetime, human factor issues at work have gained importance. This is paralleled by legal initiatives in many countries, which leads to an increase in regulations that enforce occupational safety in logistics [2]. However, the changes are very slow and many employers are very conservative and insist that improved conditions of work cannot return financial contributions within a reasonable time. A low cost of labour often represents a competitive advantage and a high percentage of absenteeism can be mitigated by part-time employment in combination with extended working hours.

The focus of this study is on picker-to-part order picking systems that are characterized by being labour-intensive. The paper contributes to the existing literature on manual order picking and conceptual framework that explores how could human factor be integrated into manual order picking systems. We tend to identify fruitful avenues for research to develop. Proposals should be formulated in such a way that their usefulness would be also recognised by the managers. This paper therefore proposes to address the following research questions:

- *RQ1. What is being researched in manual order picking?*
- *RQ2. How does research in manual order picking addresses the challenge of human as central operator?*
- *RQ3. What are the promising avenues for research regarding integration of changing characteristics of human in manual order picking?*

Conducting a systematic literature review constitutes a comprehensive approach to map out the content of the research work in the field of manual order picking by scoping its domain and core issues. Previous review [2] helped us to shorten our research work, to improve existing conclusions and create comprehensive research staring point. Overall, this paper makes contribution in linking broader debates on knowledge creation to the field of human in manual order picking. The paper is structured as follows. First, we discuss the definitions of manual order picking and some related concepts. The following section provides details about the methodological approach adopted to conduct the literature review. Finally, following the presentation of key findings, the paper discusses the promising avenues for research regarding integration of varying characteristics of human in manual order picking.

2. MANUAL ORDER PICKING SYSTEM

Order picking activities are performed by humans (manual systems) or machines (automatic systems). It is estimated that more than 80 % of warehouses are operated manually [5,6]. Picked item can be whole stock keeping unit (pallet, barrel, bag) or less than stock keeping unit, so called order picking unit (package, wrapping, single product). Usually they are weighing from a few grams up to 25 kilograms or more.

In general, order picking systems involving humans can be organized as parts-to-picker or picker-to-parts systems. Parts-to-picker systems are automated to some extend and usually include automated storage and retrieval systems (AS/RS) using cranes to retrieve loads (pallets or bins) or rotating storage locations in carousel system. At the picking position the order picker takes the required number of pieces. This type of system is also called a unit-load or end-of-aisle order-picking system [5]. In such systems order picker is free from walking, half-sitting position is possible, and work units are mostly manipulated in an ergonomically optimal area.

Picker-to-parts systems are systems where the picking units are placed in fixed storage locations and the order picker walks to single products according to the order list [15]. They are cheaper at implementation phase but more onerous for employee and management. Two types of picker-to-parts systems are distinguished: low-level picking and high-level picking [2]. In low-level picking systems, the order picker picks requested items from storage racks or bins, while travelling along the storage aisles. In high-level or a man-aboard picking systems the order picker travels to the pick locations on board of a lifting order-pick truck or crane (person-on-board AS/RS), performing picks from the appropriate locations. Picker-to-parts systems are increasingly labour intensive, for example industry has come up with innovative solutions, making it possible to attain productivity up to 1,000 picks per person hour [5]. Productivity in manual order picking system largely depends on combination of layout, storage policy, picking policy, routing policy and order accumulation method (Figure 1).

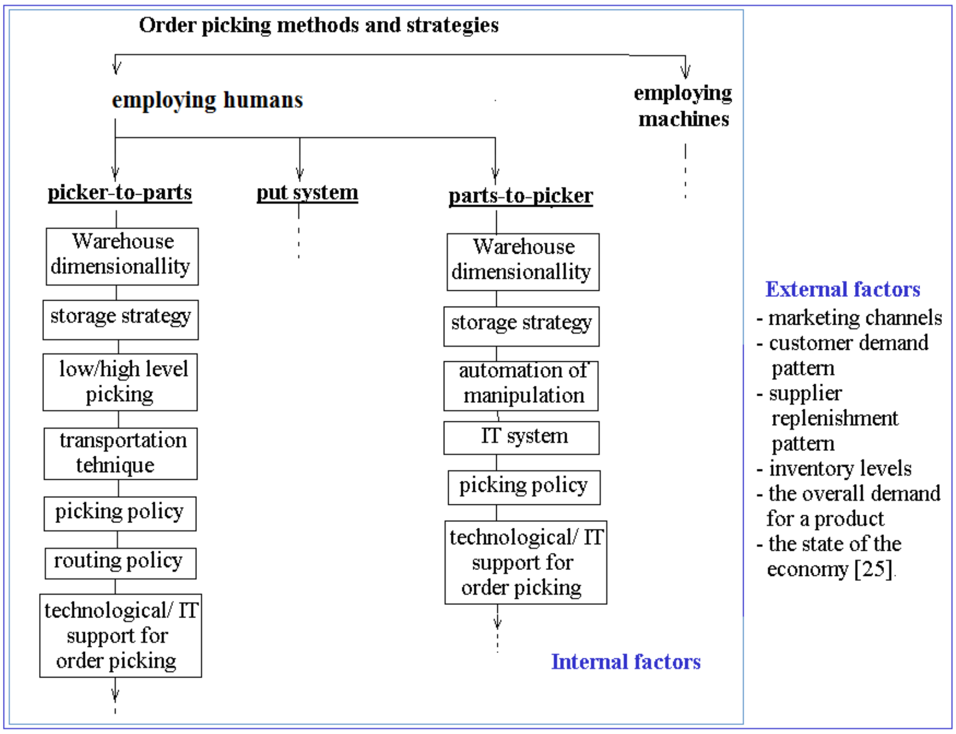

Figure 1 – Various classifications of order-picking systems
(Source: Reworked from [5] and considering [2])

Put systems, or order distribution systems, is a version of picking system which consist of a retrieval and distribution process, and can be done in a parts-to-picker or picker-to-parts manner First, items have to be retrieved in bulk. Second, the carrier (usually a bin) with these pre-picked units is offered to an order picker who distributes them over customer orders. [5 in 2]

Storage policies assign picking units to storage locations or buffer areas. Picking units may be assigned to locations randomly, volume-based to significantly reduce travel time [19,20] and class-based demanding less complex IT support [21].

Picking policies determine which picking units are placed on a pick list and subsequently retrieved from their storage locations by a single picker [5]. In the planning stage, a choice can be made between discrete (single-order) picking, grouping of several customer orders into one picking order (batching) or dividing orders into zones (zoning).

Routing policies determine the picking sequence of picking units on the pick list. The simplest routing heuristic is S-shape policy according to which order picker enters every aisle where an item has to be picked and traverses the entire aisle [24]. Another very simple routing heuristic is “return policy” where the order-picker enters and leaves aisles containing items to be picked from the front aisle. A “midpoint routing policy” is similar to a return method on two halves of a warehouse. Only the first and last aisle visited are traversed entirely. Largest Gap policy requires that all aisles that contain even one item to be picked are left at the same side as they were entered, except the first and last visited which are traversed entirely. Composite routing heuristics, combining previously mentioned simple ones, are also practiced.

Low-level, picker-to-parts order-picking systems employing humans, who perform multiple picks per route, form the very large majority of picking systems in warehouses worldwide, over 80% of all order-picking systems in Western Europe [2].

The design of real order-picking systems can be complicated due to a wide spectrum of external and internal factors which impact design choices [2] (Figure 1). External factors include marketing channels, customer demand pattern, supplier replenishment pattern and inventory levels, the overall demand for a product, and the state of the economy [25]. Internal factors include system characteristics (mechanization level, information availability and layout/equipment), organization, and operational policies (routing, storage, batching, zoning, order release mode) of order picking systems [25].

3. METHODOLOGY

This paper is based upon a review of scientific articles identified in relevant journals across the fields of order picking, picker-to-parts and human/human factor. This literature review provides a snapshot of the diversity of practices present in order picking literature. It does not pretend to cover the entirety of the literature but rather offer an informative evaluation of purposefully selected literature in order picking, which will serve to answer previously outlined research questions.

We were not limited to certain time period, although we were most interested in current dialogue. In terms of thematic scope, themes were drawn from both the order picking and the human factor thematic area. Hence we used a combination of terms related to both areas (e.g. order picking AND human factor), which helped identify articles that consider human factor in order-picking systems. Of course there are much more papers regarding order-picking systems (not involving human factors) and regarding human factors (not specifically in order-picking).

A literature review has been performed in several steps:
- searching for articles by keywords and selection of the relevant;
- compiled list of the scientific journals in which relevant articles were published;
- searching for other relevant articles and established dialogue in the scientific journals from the list.

The review has been limited to peer-reviewed publications as a way to guarantee a certain level of quality [28], and to ensure consistency between the themes and sources by carefully selecting journals, which covered areas from both the order picking and human factor thematic area. Eighteen journals in the field of order picking and the field of human factor were selected. Searches were conducted on journals' web sites as well as the database Web of Science. The majority of papers are from:
- International journal of production research (9),
- International Journal of Industrial Ergonomics (6)
- International journal of operational & production management (5),
- European journal of operational research (4),
- International journal of production economics (3),
- IIE Transactions (4),
- Human factors and ergonomics in manufacturing & service industry (2),
- Applied Ergonomics (2).

A closer analysis of the abstracts allowed distinguishing between relevant and irrelevant articles.

4. RESULTS

In this paper we concentrate on low-level, picker-to-parts order-picking systems employing humans (and with multiple picks per route). As already said, these systems form the very large majority of picking systems in warehouses worldwide, over 80 % of all order-picking systems in Western Europe. Surprisingly, academic order-picking literature focuses more on high-level picking and AS/RS systems.

4.1 What is being researched in manual order picking?

To support the design, management and operations of picker-to-part systems, various mathematical decision support models have been developed over the last decades (see, for a review, [5,37]). The most common objective of these decision support models is to minimise the travel distance or the picking time of an order by determining:

- the facility layout [45,46,47,48]
- the internal configuration of shelves and aisles [53],
- the routing of order pickers [38],
- the picking policy [11,16],
- the assignment of products to storage or buffer spaces [5,12,39,40,41,42,43,44].

The most common objective of order-picking systems is to maximise the service level subject to resource constraints such as labour, machines, and capital [25]. The service level is composed of a variety of factors such as average and variation of order delivery time, order integrity, and accuracy. A crucial link between order picking and service level is that faster an order can be retrieved, sooner it is available for shipping to the customer. Although various case studies have shown that also activities other than travel may substantially contribute to order-picking time [18,27], travel is often the dominant component. Travel time costs labour hours but does not add value. For manual order picking systems, the travel time is an increasing function of the travel distance [7,12,19,23,26]. Consequently, the travel distance is often considered as a primary objective in warehouse design and optimization. Since gains in productivity are mostly achieved by reduction of travelling distances, the implications on saved energy for order-picker trucks could be tremendous and in compliance with contemporary greening concept [24]. Another important objective would be minimising the total cost that may include both investment and operational costs. Other objectives, which are often taken into consideration in warehouse design and optimisation, are minimising the throughput time of an order, minimising the overall throughput time to complete a batch of orders, maximising the use of space, maximise the use of equipment, maximising the use of labour and maximising the accessibility to all items.

4.2 How does research in manual order picking addresses the challenge of human as central operator?

A thorough literature review [2] published in 2015 showed that the large majority of decision support models designed through the lens of order picking as business process solely concentrated on the short-term economic impact of order picking, but neglected the influence of the order picking process on the human operator and vice versa, the influence of the human operator on the order picking process. Nevertheless we trace the growing number of researchers who believe that it is necessary to consider human factors in addition to economic aspects in designing labour-intensive manual order picking systems in order to guarantee a high level of productivity and efficiency and to make sure that decision support models reflect reality as good as possible. The pressure built up across the supply chain is recognized for being an area in which there is a great potential for a significant, if not large, improvement in terms of health and safety standards [30,31]. Pressures for cost reduction and the market's unpredictable, shifting demands result in longer work shifts, a high rate of outsourcing and more rapid rates of production. These indirect effects in the supply chain stand to create additional barriers to adequate health and safety in the workplace [34]. Logistics systems represent a fundamental and at times underappreciated industrial and securities risk.

There are already some propositions about aspects of needed renovations in order picking systems. Changes that might be made in the workplace in hopes of improving the work conditions of employees can be divided into three groups [33]:

- technical interventions (redesign of the physical environment, assistance to workers, and tools, etc.),
- organisational and administrative interventions (shift rotation, increased attention on part of managers, incorporation of ergonomics, etc.),
- behaviour-change interventions (promoting physical fitness and exercise, raising awareness of workplace health and safety issues, etc.).

We can trace also a much wider reflection [81], suggesting action at the level of anthropometric mega-system in which order picking system is only one of subsystems. In this idea, call to meeting the needs of people, both obvious (self-realisation) and hidden and nonstandard stands out because, in relation to the rest of the existing order picking literature, this seems currently the most difficult to reach.

Much literature written before 2010 study specific manual warehousing and order picking tasks and related workload from an ergonomic point of view [75]. Authors developed or reused from other work areas several more or less simple assessment methods based on observations and interviews to define workload, risk factors, harmful awkward postures, work factors related to MSD risk:

- proposed recommendations and ergonomic guidelines for different warehousing tasks [63],
- determination of the physiological work load, perceived exertion and recovery from work for warehouses with different degree of automation [64],
- development of an ergonomic workload stress index model based on fuzzy set theory which was validated in a warehouse environment [65],
- video recordings were used to assess risk factors inherent in warehouse material handling that may lead to MSD [35]
- interviews and video recordings were used to identify different ergonomic factors that hinder work in warehouses, such as awkward body postures and time pressure [66],
- a biomechanical evaluation model was employed to compute the forces and moments at various body joints related to the body posture during the warehousing tasks lifting, lowering, pushing and pulling [67,68,69],
- a checklist was proposed that can be used as a rapid screening tool to identify harmful awkward postures in warehousing tasks [70],
- photographs of warehousing workers were token and the positions of the body and lower limbs were analysed during handing of loads [71],
- an interview approach was presented to explore which ergonomic interventions are necessary to reduce the risk for MSD in a warehouse [72],
- different ergonomic assessment tools were applied (namely the NIOSH lifting equation, the Static Strength Prediction Program, the Lumbar Motion Monitor, and the Borg psychophysical assessment of effort) to identify warehousing tasks that are problematic with regard to MSD [73],
- complex manual work was assessed by interactive operator assessment of video recordings [35].

Prior to 2010 physical work exposure characteristics have been described mostly in gross categorical terms like heavy work, lifting and forceful movements. Shift from the pioneering efforts toward more comprehensive scientific research, in the direction of work demands characterization in a much more quantitative fashion, was gained with:

- first use of sophisticated instrumentation continuously documenting 390 physical exposures during lifting in four types of distribution centers throughout work [78],
- use of an automatic exposure tracking system to show in a quantitative way which work factors are related to MSD risk in distribution centres [74].

New approaches resulted in findings that [78],

- exposures vary as a function of the type of distribution center,
- static load and load moment measures greatly under-represent true (dynamic) load and load moment exposures to workers,
- lift durations averaged 11–12% of the cycle time in distribution environments,
- distribution workers are commonly exposed to greater extreme loads and move much more rapidly than manufacturing employees.

In most above papers we witness partial attempts to locally improve productivity and create more people-friendly working environment. Because order picking is a dynamic system based on various external and internal factors, it was soon recognized that it is necessary to:

- monitor operators in real time with help of measuring equipment, which should not hinder employee in performing tasks,
- redirect focus from mostly qualitative research to quantitative,
- consider human factor already in the phase of order picking system design, planning and management.

Order picker system is initially recognized as an example of system, consisted from one or more ergonomic man – technical sub-systems (Figure 2), in which many factors influence on human and vice versa, human impacts on the functioning of the system.

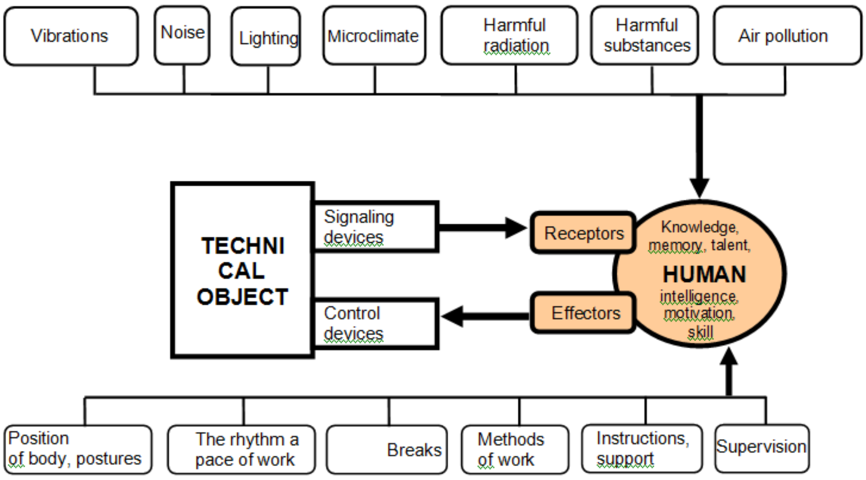

Figure 1 – Various classifications of order-picking systems (Source: adapted from [80] included in [81])

As presented above, we traced critical mass of persuading scientific papers demonstrating that the consideration of the human factor in order picking is reasonable and necessary. Including ergonomics evaluations in the human operations analysis is a win-win approach due to the interaction between productivity, motion efficiency and operational safety [52]. In addition, some authors noted that considering ergonomic aspects is not only relevant for reducing health risks, but that it may also improve the performance and quality of order picking significantly [2,36]. Exactly these findings are essential for further research, which followed after 2010 and will be followed in the future.

In conjunction with the penetration of systems thinking in order picking research stream, more recent scientific literature, published after 2014, tries to determine how to integrate the human factor in the processes of planning and management of order picking systems with the aim of increasing productivity while maintaining the health of employees. Due to the impact of ergonomic aspects on the performance of order picking, more and more authors recently call for the integration of ergonomic aspects into decision support models for order picking designing and operating [2,54]. The response is very weak in quantity of works. In most cases those researchers who are calling for adding new research perspectives to order picking research area later also participate in further research. Below, we describe some of explored areas chronologically from 2008 onwards:

- Storage assignment policy considering human factor was determined. It helps to reduce total fulfilment time with the concept of golden zone storage, where high-demand items are stored in the area between a picker's waist and shoulders [55];
- Questions regarding micro and macro ergonomics were addressed, based upon a distribution center-design point of view, broached the topics of logistics and ergonomics by way packaging structure versus volume and weight in application to muscular-skeletal injuries, risks, and accidents [32],
- workplace stress factors were researched that can potentially cause numerous problems related to health and, by extension, absenteeism [33];
- A framework for scheduling human tasks that account for physical and/or cognitive human characteristics and behaviours was established [77];
- Order selection process was researched in a refrigerated dairy factory, which is considered as extremely unfriendly environment for humans. The new system was proposed to increase productivity by 8.4%, improve workers' satisfaction, simplify tasks, improve work quality, reduce delay in invoicing [51];
- The storing of parts according to their picking frequency was proposed: items with a low picking frequency and/or a high weight should be positioned in low shelf floors, while items picked more often should stay in a height of 0.85 m up to shoulder height [61];
- It was proved that human availability is strictly correlated to the ergonomics aspects [62];
- Many manufacturers of warehouse equipment, such as SSI Schäfer, Treston, Swisslog, Vanderlande Industries and Knapp, introduced storage tools that make manual order picking easier to perform by workers. Producers of forklifts like Linde, Jungheinrich, Toyota and others invest heavily in research and development of ergonomically designed forklifts [59];

- A guideline for smart cart ergonomics design based on testing and interviewing was provided. A smart cart helps workers to perform an efficient picking operation without human errors and consequently cost problems [79];
- New planning procedures that consider human factor were proposed to be implemented into Warehouse Management or Enterprise Resource Planning systems, which could help to generate more realistic plans for order picking [2];
- Learning was recognized as important impact factor influencing order picking efficiency [9];
- Two functions for modeling the relation of the human availability and the rest allowance to the ergonomics level have been proposed. Furthermore, two total cost models have been presented, one referring to a basic system and one to a system with the employment of stand-by units, to evaluate how ergonomics impacts on the total cost of the systems [62];
- Route deviations occur frequently in practice. More or less stochastic realization of planned activities by human operators and behavioural issues in order picking and routing policies for order pickers were researched in parallel to define influence on order picking performance [76].

In recent years, further notable progress was achieved in area of measurement and ergonomics assessment methods with goal to monitor order picking operators in real time with help of measuring equipment, which should not hinder employee in performing tasks. Over time measurement and ergonomics assessment methods have turned out to be a major research challenge. Order picking activities are difficult to assess from ergonomics perspective because involvement of all body parts and a wide pallet of different postures, machine interfaces and loads. The only logical approach is often seen by using more than one ergonomics evaluation method resulting in a globally accurate assessment. This increases assessment complexity and time consumption. Popular, widespread ergonomics evaluation methods are OWAS, RULA, OCRA, the NIOSH lifting equation, among others. These and similar methods can be applied using different tools, which can be divided into self-report, operator observation, virtual simulations, and direct measurement methods, where each method has its specific limitations, advantages and applications [56,57]. In general, the results of these methods are semi-quantitative indices, and they are typically applied to study macro-activities without analysing each elementary activity that composes the examined task in detail. Garg, Chaffin, and Herrin [58] introduced another method for ergonomics evaluations of manual tasks based on the energy expenditure assessment of standard operations execution as a function of oxygen consumption. High workloads lead to a significant consumption of metabolic cost, causing health risks for the workers (ISO 8996, 2014).

Much effort is invested in the development of full-body systems for the real-time ergonomics evaluations of manual material handling in warehouse environments, where all parts of the body are interested during the activities execution. Two years ago presented system is based on inertial sensors with integrated compensation of magnetic interference and long wireless connection that permit its use also in heavy industrial applications [50]. New system upgraded previous attempts [49] that did not base on the using of a full body motion capture system A specific set of tools has been developed in order to elaborate the collected motion data and give real time evaluation and feedback of ergonomics based on the most used methodologies and extended with others advanced ad hoc tools, such as hands positions analysis, travel distance, time and methods collection calculations. The system has been applied to two different warehouses both for the re-design of the storage area and successively management of the typical warehousing activities, such as picking, packing and others, reducing the risk of musculoskeletal disorders and simultaneous increasing of productivity of systems. The feedback given from these analyses has permitted to define appropriate suggestions to take into account in the re-design of the warehouse.

Advanced ergonomics measuring and assessment methods and equipment are important base for further manual order picking systems development. For example, Battini, Glock, Grosse, Persona and Sgarbossa [36] were the first researchers who based on described measurement method included the rest allowance concept in warehouse design and management, and especially in storage assignment models. Energy expenditure was integrated into the function of total order picking time. This approach allowed the calculation of an additional rest time that is required to maintain a low level of fatigue.

5. CONCLUSIONS

General conclusion is that it is necessary to consider human factors in addition to economic aspects in designing labour-intensive manual order picking systems to guarantee a sustainable high level of productivity and efficiency and to make sure that decision support models reflect reality as good as possible. Below, we list some promising avenues for research regarding integration of human factor in low-level, picker-to-parts order picking systems employing humans.

5.1 Promising avenues for research regarding integration of changing characteristics of human in manual order picking

Grosse et al. [2] identified several important issues that should be considered in the design of order picking systems, which is supported by the development of suitable order picking planning models that explicitly consider human factors. These issues are:

- humans are central to order picking systems, and the human–system interaction can be a determining factor for system performance, quality and worker health,
- task times are not deterministic,
- workers are heterogeneous,
- human errors occur,
- human learning, forgetting, boredom and tiredness occur,
- workers are exposed to occupational health and safety issues.

Order pickers perform picking operations in working environments that differentiate according to used policies, equipment, technologies and other. From IT perspective there is an opportunity to develop smart planning system with control loop based on real time data about human status, load and progress in process which corrects plan of further activities based on comparison of planned parameters with actual.

The design of order picking systems is very important for later business success and itself complicated due to a wide spectrum of external and internal factors which impact design choices. On the first sight it is very difficult to define the relationship between external factors, which include marketing channels, customer demand pattern, supplier replenishment pattern and inventory levels, the overall demand for a product, and the state of the economy [25], and human factor. Current research efforts are more focused in integration of human factor to some issues regarding internal factors, which include system characteristics (mechanization level, information availability and layout/equipment), organization, and operational policies (routing, storage, batching, zoning, and order release mode) of order-picking systems. We observed some contributions integrating human factor to order picking area regarding equipment and vehicles design, workplace design, lowering stress, packaging characteristics, storage assignment policy etc. Because we know that learning can influent productivity significantly there is a great need to reconsider proposed mathematical models for routing. If we summarize:

- Interaction between external factors and human factor is missing;
- Every research from the area low-level, picker-to-parts order picking systems employing humans should include consideration about human factor;
- Research findings from the area low-level, picker-to-parts order picking systems employing humans should be reconsidered from the view point of human factor before implication or upgrading.

Among others also order picking processes are increasingly digitalizing. New technologies are being introduced, such as smart glasses and pick-by-voice. We were able to find only one paper which includes human factor about exploring the role of picker personality in predicting picking performance with pick by voice, pick to light and RF-terminal picking [60]. Producers often present their product used in order picking systems as well as ergonomics, but scientific literatures lack of proves.

New planning procedures that consider human factor could be implemented into Warehouse Management or Enterprise Resource Planning systems, which could help to generate more realistic plans for order picking. Although Grosse et al. [2] started to build conceptual framework to facilitate such integration, we did not notice that researchers would be researching the impact of scheduling on order pickers although a framework for scheduling human tasks that account for physical and/or cognitive human characteristics and behaviors was established [77]. Scheduling is differentiated from planning in fact that planning defines “What” and “How”, while scheduling defines “When” and “Who”. Answers on “How”, “When” and “Who” directly relate to a person who later carry out certain activity.

We observed that managers often do not understand the need for integrating human factor in manual order picking systems. Investments in logistics in general are often of secondary importance, while improving ergonomic conditions in logistic processes might be rated even as of tertiary importance. That could be improved if the correlation between human factor and order picking system would be further researched in terms of influence on productivity (travel distance, less absence from work) or even to introduce new indicators.

A lot can be also done with connecting right measuring and assessment methods to fatigue management system. Measuring methods and equipment should be easy to use, cheap to implement and results should be easy to read and understand their applied value.

In the literature review we met a lot of researches of individual parts of order picking system, for example human-machine interfaces, policies, layouts etc. In this way, there are many opportunities for improvements based on a holistic and systemic approach. The advantage of the diversity of published results is that it can be said that there is an excellent basis for development of comprehensive approach to designing and operating of manual order picking systems.

6. REFERENCES

[1] Eurofound: *Improving working conditions in occupations with multiple disadvantages*, Office of the European Union, Luxembourg, 2015.

[2] Grosse, E. H., Glock, C. H., Jaber, M. J., Neumann, P. W.: *Incorporating human factors in order picking planning models: framework and research opportunities*, International Journal of Production Research, 53(2015)3, 695-717.

[3] Frazelle, E. A.: *World-class Warehousing and Material Handling*, McGraw-Hill, New York, 2002.

[4] Tompkins, J. A., White, Y. A., Bozer, E. H., Tanchoco. J. M. A.: *Facilities Planning,* 4th ed., Wiley, Hoboken, NJ, 2010.

[5] De Koster, R., Le-Duc, T., Roodbergen, K. J.: *Design and control of warehouse order picking: a literature review*, European Journal of Operational Research, 182(2007)2, 481-501.

[6] Napolitano, M.: *2012 Warehouse/DC Operations Survey: Mixed Signals*, Modern Materials Handling, 51(2012)11, 48-56.

[7] Petersen, C. G.: *The impact of routing and storage policies on warehouse efficiency*, International Journal Operational & Production Management, 19(1999)10, 1053-1064.

[8] Le-Duc, T., De Koster, B. M.: *Travel distance estimation and storage zone optimization in a 2-block class-based storage strategy warehouse*, International Journal of Production Research, 43(2005)17, 3561-3581.

[9] Grosse, E. H, Glock, C. H.: *The effect of worker learning on manual order picking processes*, International Journal of Production Economics, 170(2015)PartC, 882-890.

[10] Dawson, D., McCulloch, K.: *Managing fatigue: it's about sleep*, Sleep medicine reviews, 9(2005)5, 365-380.

[11] Ruben, R. A., Jacobs, F. R.: *Batch construction heuristics and storage assignment strategies for walk/ride and pick systems*, Management Science, 45(1999)4, 575-596.

[12] Petersen, C. G., Aase, G.: *A comparison of picking, storage, and routing policies in manual order picking*, International Journal of Production Economics, 92(2004), 11-19.

[13] Schneider, E., Irastorza, X.: *Work-Related Musculoskeletal Disorders in the EU*, European Agency for Safety and Health at Work, Luxembourg, 2010.

[14] Marras, W. S., Davis, K. G., Kirking, B. C., Granata, K. P.: Spine loading and trunk kinematic changes during team lifting, Proceedings of the Human Factors and Ergonomics Society 41st Annual Meeting 1997, Albuquerque, Santa Monica, CA.

[15] De Koster, R.: *How to assess a warehouse operation in a single tour*, Report, RSM Erasmus University, Netherlands, 2004.

[16] Gibson, D. R., Sharp, G. P.: *Order batching procedures*, European Journal of Operational Research, 58(1992)1, 57-67.

[17] Petersen, C. G.: *An evaluation of order picking policies for mail order companies*, Production and Operations Management, 9(2000)4, 319-335.

[18] De Koster, R., Roodbergen, K. J., Van Voorden, R.: *Reduction of walking time in the distribution center of De Bijenkorf*, in M.G. Speranza, P. Stähly (Eds.): *New Trends in Distribution Logistics*, Springer, Berlin, 1999, 215-234.

[19] Jarvis, J. M., McDowell, E. D.: *Optimal product layout in an order picking warehouse*, IIE Transactions, 23(1991)1, 93-102.

[20] Petersen, C. G., Schmenner, R. W.: *An evaluation of routing and volume-based storage policies in an order picking operation*, Decision Sciences, 30(1999)2, 481-501.
[21] Eynan, A., Rosenblatt, M. J.: *Establishing Zones in Single-Command Class-based Rectangular AS/RS*, IIE Transactions, 26(1994), 38-46.
[22] Ratliff, H. D., Rosenthal, A.S.: *Order picking in a rectangular warehouse: a solvable case of the traveling salesman problem*, Operations Research, 31(1983)3, 507-521.
[23] Hall, R. W.: *Distance approximation for routing manual pickers in a warehouse*, IIE Transactions, 25(1993), 77-87.
[24] Đukić, G., Česnik, V., Opetuk, T.: *Order-picking Methods and Technologies for Greener Warehousing*, Strojarstvo, 52(2010)1, 23-31.
[25] Goetschalckx, M., Ashayeri, J.: *Classification and design of order picking systems*, Logistics World, June (1989), 99-106.
[26] Roodbergen, K. J., De Koster, R.: *Routing methods for warehouses with multiple cross aisles*, International Journal of Production Research, 39(2001)9, 1865-1883.
[27] Dekker, R., de Koster, R., Roodbergen, K. J., Van Kalleveen, H.: *Improving order-picking response time at Ankor's warehouse*, Interfaces, 34(2004)4, 303-313.
[28] Burgess, K., Singh, P. J., Koroglu, R.: *Supply chain management: a structured literature review and implications for future research*, International Journal of Operations & Production Management, 26(2006)7, 703-729.
[29] Lee, E. Y., Kim, M. K., Chang, Y. S.: Development of an Advanced Picking Station Considering Human Factors, Human factors and ergonomics in manufacturing & service industries, 26(2016)6, 700-712.
[30] HSC: *Regulation and recognition: Towards good performance in health and safety*, HSC, London, 2004.
[31] Loos, M. J., Merino, E., Rodriguez, C. M. T.: *Mapping the state of the art of ergonomics within logistics*, Scientometrics, 109(2016), 85-101.
[32] Acosta, G. G., Morales, K. L.: *Macroergonomic study of food sector company distribution centres*, Applied ergonomics, 39(2008)4, 439-449.
[33] Reinhold, K. Tint, P., Viiu, T., Silver, S.: *Innovations at workplace: improvement of ergonomics*, Engineering Economics, 5(2008), 85-94.
[34] Lloyd, C., James, S.: *Too much pressure? Retailer power and occupational health and safety in the food processing industry*, Work, Employment & Society, 22(2008)4, 713-730.
[35] Kadeforsa, R., Forsman, M.: *Ergonomic evaluation of complex work: a participative approach employing video–computer interaction, exemplified in a study of order picking*, International Journal of Industrial Ergonomics, 25(2000)4, 435-445.
[36] Battini, D., Glock, C. H., Grosse, E. H., Persona, A., Sgarbossa, F.: *Human energy expenditure in order picking storage assignment: A bi-objective method*, Computers & Industrial Engineering, 94(2016), 147-157.
[37] Gu, J., Goetschalckx, M., McGinnis, L. F.: *Research on warehouse operation: A comprehensive review*, European Journal of Operational Research, 177(2007)1, 1-21.
[38] Petersen, C. G.: *An evaluation of order picking routeing policies*, International Journal of Operations & Production Management, 17(1997)11, 1098-1111.
[39] Rao, S. S., Adil, G. K.: *Class-based storage with exact S-shaped traversal routeing in low-level picker-to-part systems*, International Journal of Production Research, 51(2013)16, 4979-4996.
[40] Battini, D., Calzavara, M., Persona, A., Sgarbossa, F.: *Order picking system design: The storage assignment and travel distance estimation (SA&TDE) joint method*, International Journal of Production Research, 53(2015)4, 1077-1093.
[41] Chackelson, C., Errasti, A., Ciprés, D., Lahoz, F.: *Evaluating order picking performance trade-offs by configuring main operating strategies in a retail distributor: A Design of Experiments approach*. International Journal of Production Research, 51(2013)20, 6097-6109.
[42] Ene, S., Öztürk, N.: *Storage location assignment and order picking optimization in the automotive industry,* International Journal of Advanced Manufacturing Technology, 60(2012)5-8, 787-797.
[43] Chuang, Y. F., Lee, H. T., Laih, Y. C.: *Item-associated cluster assignment model on storage allocation problems*, Computers and Industrial Engineering, 63(2012)4, 1171-1177.
[44] Glock, C. H., Grosse, E. H.: *Storage policies and order picking strategies in U-shaped order-picking systems with a movable base*, International Journal of Production Research, 50(2012)16, 4344-4357.

[45] Tompkins, J. A., White, J. A., Bozer, Y. A., Frazelle, E. H., Tanchoco, J. M. A.: *Facilities Planning*, John Wiley & Sons, NJ, 2003.
[46] Meller, R. D., Gau, K. Y.: *The facility layout problem: recent and emerging trends and perspectives*, Journal of Manufacturing Systems, 15(1996)5, 351-366.
[47] Heragu, S. S., Du, L., Mantel, R. J., Schuur, P. C.: *Mathematical model for warehouse design and product allocation*, International Journal of Production Research, 43(2005), 327-338.
[48] Petersen, C. G.: *Considerations in order picking zone configuration*, International Journal of Operations & Production Management, 27(2002)7, 793-805.
[49] Vignais, N., Miezal, M., Bleser, G., Mura, K., Gorecky, D., Marin, F.: *Innovative system for real-time ergonomic feedback in industrial manufacturing,* Applied Ergonomics, 44(2013)4, 566-574.
[50] Battini, D., Persona, A., Sgarbossa, F.: *Innovative real-time system to integrate ergonomic evaluations into warehouse design and management*, Computers & Industrial Engineering, 77 (2014), 1-10.
[51] Yeow, P. H. P., Goomas, D. T.: *Ergonomics Improvement in Order Selection in a Refrigerated Environment,* Human factors and ergonomics in manufacturing & service industries, 24(2014)3, 262-274.
[52] Battini, D., Faccio, M., Persona, A., Sgarbossa, F.: *Design of the optimal feeding policy in an assembly system*, International Journal of Production Economics, 121(2009), 233-254.
[53] Vijaya Ramnatha, B., Suresh Kumarb, C., Riyaz M. R., Venkataramand, K., Elanchezhiane, C., Sathishf, S.: *Analysis of Occupational Safety and Health of Workers by Implementing Ergonomic Based Kitting Assembly System*, Procedia Engineering, 97(2014), 1788-1797.
[54] Boysen, N., Emde, S., Hoeck, M., Kauderer, M.: *A survey on part logistics in the automotive industry*, European Journal of Operational Research 242(2015)1, 107-120.
[55] Petersen, C. G., Siu, C., Heiser, D. R.: *Improving order picking performance utilizing slotting and golden zone storage*, International Journal of Operations & Production Management 25(2005)10, 997-1012.
[56] David, G. C.: *Ergonomic methods for assessing exposure to risk factors for work-related musculoskeletal disorders*, Occupational Medicine, 55(2005) 3, 190-199.
[57] Li, G., Buckle, P.*: Current techniques for assessing physical exposure to work-related musculoskeletal risks, with emphasis on posture-based methods*, Ergonomics, 42(1999)5, 674-695.
[58] Garg, A., Chaffin, D. B., Herrin, G. D.: *Prediction of metabolic rates for manual materials handling jobs*, The American Industrial Hygiene Association Journal, 39(1978)8, 661-674.
[59] Gajšek, B., Đukić, G., Opetuk, T.: *Review of ergonomic solutions to protect from injuries of lower back in case of forklifts drivers*, in: Management of Technology – Step to Sustainable, Brela, Hrvatska, 2015.
[60] de Vries, J., de Koster, R., Stam, D.: *Exploring the role of picker personality in predicting picking performance with pick by voice, pick to light and RF-terminal picking*, International journal of production research, 54(2016)8, 2260-2274.
[61] Weisner, K., Deuse, J.: *Assessment Methodology to Design an Ergonomic and Sustainable Order Picking System Using Motion Capturing Systems*, Procedia CIRP, 17(2014), 422-427.
[62] Battini, D., Calzavara, M., Persona, A., Sgarbossa, F.: *Linking human availability and ergonomics parameters in order-picking systems*, IFAC-PapersOnLine, 48(2015)3, 345-350.
[63] Parker, M.: *Incorporating ergonomics into the concurrent engineering of a new warehouse,* International Journal of Industrial Ergonomics, 20(1997)3, 251-257.
[64] Braam, I. T. J., van Dormolen, M., Frings-Dresen, M. H.: *The work load of warehouse workers in three different working systems*, International Journal of Industrial Ergonomics, 17(1996)6, 469-480.
[65] Chen, J. G., Jung, H. S., Peacock, B. J.: *A fuzzy sets modelling approach for ergonomic workload stress analysis*, International Journal of Industrial Ergonomics, 13(1994)3, 189-216.
[66] St-Vincent, M., Denis, D., Imbeau, D., Laberge, M.: *Work factors affecting manual materials handling in a warehouse superstore*, International Journal of Industrial Ergonomics, 35(2005)1, 33-46.
[67] Garg, A., Chaffin, D. B., Gary D. H.: *Prediction of metabolic rates for manual materials handling jobs*, The American Industrial Hygiene Association Journal, 39(1978)8, 661-674.
[68] Garg, A.: *Biomechanical and ergonomic stresses in warehouse operations,* IIE Transactions, 18(1986) 3, 246-250.
[69] Garg, A.: *Ergonomic, Biomechanical and Physiological Stresses from Manual Materials Handling in Grocery Distribution Centers*, Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 44(2000)28, 431-432.

[70] Keyserling, W. M., Brouwer, M., Silverstein, B. A.: *A checklist for evaluating ergonomic risk factors resulting from awkward postures of the legs, trunk and neck*, International Journal of Industrial Ergonomics, 9(1992)4, 283-301.
[71] Kuorinka, I., Lortie, M., Gautreau, M.: *Manual handling in warehouses: the illusion of correct working postures*, Ergonomics, 37(1995)4, 655-661.
[72] Lavender, S. A., Sommerich, C. M., Johnson, M. R., Radin, Z.: *Developing Ergonomic Interventions to Reduce Musculoskeletal Disorders in Grocery Distribution Centers*, Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 54(2010)15, 1229-1233.
[73] Marklin, R. W., Wilzbacher, J. R.: *Four assessment tools of ergonomics interventions: case study at an electric utility's warehouse system,* American Industrial Hygiene Association Journal, 60(1999)6, 777-784.
[74] Marras, W. S., Lavender, S. A., Ferguson, S. A., Splittstoesser, R. E., Yang, G.: *Quantitative biomechanical workplace exposure measures: distribution centers*, Journal of Electromyography and Kinesiology, 20(2010)5, 813-822.
[75] Calzavara, M., Glock, C. H., Grosse, E.H., Persona, A., Sgarbossa, F.: *Models for an ergonomic evaluation of order picking from different rack layouts*, IFAC-PapersOnLine, 49(2016)12, 1715-1720.
[76] Elbert, R. M., Franzke, T., Glock, C. H., Grosse, E. H.: *The effects of human behavior on the efficiency of routing policies in order picking: the case of route deviations*, Computers & Industrial Engineering - Special Issue Human factors in industrial and logistic system design, 2016.
[77] Lodree, E. J., Geiger, C. D., Jiang, X.: *Taxonomy for integrating scheduling theory and human factors: Review and research opportunities*, International Journal of Industrial Ergonomics, 39(2009), 39-51.
[78] Marras, W. S., Lavender, S. A., Ferguson, S. A., Splittstoesser, R.E., Yang, G.: *Quantitative biomechanical workplace exposure measures: Distribution centers*, Journal of Electromyography and Kinesiology, 20(2010), 813-822.
[79] Kim, M. K., Lee, E. Y., Chang, Y. S.: *A study on the human factors for a smart cart system*, Procedia Manufacturing, 3(2015), 566-573.
[80] Tytyk, E.: *Projektowanie ergonomiczne*, Wyd. Naukowe PWN, Warszawa, Poznań, 2001.
[81] Butlewsky, M., Tytyk, E.: *The assessment criteria of the ergonomic quality of anthropotechnical mega-systems*, in: Vink, P. (Ed.): *Advances in Social and Organizational Factors*, CRC Press, Taylor and Francis Group, Boca Raton, London, New York, 2012, 298-306.