March 17th — 18th, 2021 | Darmstadt, Germany
Interdisciplinary Conference
on Production, Logistics and Traffic
www.icplt.org

How human capabilities are impacting the individual strain in manual order picking

Ralf Elbert[1], Julia Wenzel[1], Tim Steinebach[2], and Jurij Wakula[2]

[1] *Technische Universität Darmstadt, Department of Law and Economics, Darmstadt, Germany*
[2] *Technische Universität Darmstadt, Department of Mechanical Engineering, Darmstadt, Germany*

Abstract. Performance fluctuations can be identified in manual order picking processes. A possible reason might be the missing consideration of individual capabilities and each employee's constitution in the order assignment. In the present paper, those human capabilities are analysed to specify their impact on the performance of manual order picking and, in consequence, the individual strain. First, the possible impact factors are identified. Then they are evaluated by different, selected approaches for integrating them in simulation. The impact factors are used to design an agent "human" in an agent-based simulation model that estimates the human capabilities' impact in individual strain.

1 Introduction

In warehouses, picking is one of the most frequently performed processes, retaining a high proportion of manual work [1]. Various research approaches focus on minimizing the picking process's time or cost [1, 2, 3]. The consideration of the human being, stresses, and strains arising from the activity is often missing in current studies. An example of an approach considering human factors, in detail human capabilities, in manual order picking is the work of Matusiak et al. [4]. In their approach, they focus on the order picker's performance. The analysis of the overall strain on an order picker caused by the picking process is not adapted to his or her capabilities. Papers such as [4] deal with order aggregation but do not consider specific order assignments related to the order picker's capabilities. The researches of the last few years [4,5] indicate that the consideration of human factors in manual order picking is not specified in a scientific context because of the complexity of the manual order picking process and the primary influence of human capabilities on the output variables of the process (performance, quality and employee health).

More papers are dealing with the influence of human factors in the context of logistics and production systems [6]. The review results of [6] indicate that the prospective integration of human factors in the design of logistics and production systems will significantly influence the system performance. Subsequently, the order picking process's performance is strongly influenced by each employee's performance. According to [6], the prospective "human-centred modelling" is necessary as well as tools and methods for professional model builders to support decision-making in practice.

This work considers the order picker's physical capabilities as an essential basis to design an order picking system. Therefore, the order allocation can be used as an opportunity to improve order picking performance and reduce the strain on employees.

2 Research approach

A detailed consideration of each manual order picker's performance into the order assignment is necessary. Furthermore, the physical strains resulting from a high workload, which are related to the capabilities, can cause muscular-skeletal disorders. The level of strain is influenced by the order pickers' different capabilities, such as constitutional (gender, anthropometry) or dispositional characteristics (age, health). The described research studies do not include the stress and strain optimized assignment of orders to specific

operators in manual order picking. A targeted consideration of this order assignment is only possible if the employees are recognized as a heterogeneous workforce, as mentioned in [5]. This research suggests a viable solution to answer how far human capabilities impact the individual strain in manual order picking. This study's approach implies that the assignment of order pickers has not only to be adopted by individual capabilities. Therefore, the picking process's operations should be analysed depending on human capabilities and process-related factors, which are summarized in a conceptual framework.

3 Conceptual framework

The conceptual framework has to be split into two aspects. The first aspect is the analysis of the possible impact factors, which is focused on ergonomics. The second aspect is the design of an agent-based simulation model. The two aspects reflect the different research focuses: ergonomics and logistics. The simulation offers a possible method to combine both types of research streams. The individual characteristics of each order picker have not been considered in logistics simulation approaches so far. This study aims to consolidate the incoming orders in manual order picking and examine an order picker's individual performance. Simulation provides opportunities in the early planning process of order picking. It is possible to recognise the workload's influence at an early stage without any intervention in the work process. The consequences can be prevented and it can also be used as a decision-making tool.

3.1 Analysis of the possible impact factors

First of all, the order picker’s capabilities, workload and strains have to be defined in context of the stress and strain concept [7]. An order picker capability is composed of different constitutional and dispositional characteristics. Figure 1 displays the necessary ergonomic context. The possible impact factors of order picker capability are the dispositional and constitutional characteristics. Therefore, the individual strain's relevant impact factors are the workload and order picker capability based on dispositional and constitutional characteristics.

The question is how these impact factors influence the strains. The implementation must simulate how they correlate and how to combine the impact factors in a simulation. Therefore, different evaluation approaches are used for each impact factor. The impact of order picker capability and workload on the individual strain is analysed by multiplicators and the classification criteria tool "MultipLa" [8]. Furthermore, "MultipLa" evaluates the workload depending on the gender of the order picker. Multipliers are then used to calculate a workload corresponding to the order picker's capabilities. The "MultipLa" tool is discussed first, followed by the multipliers.

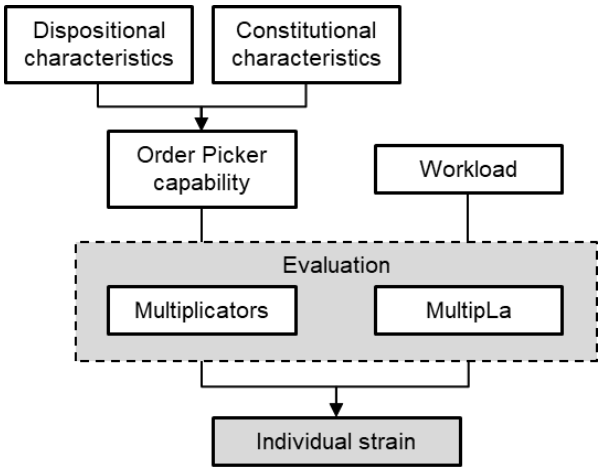

Figure 1. Impact factors and evaluation tools describing the ergonomic context.

To define the impact of the constitutional characteristics and the workload, a reference is made to the work of [9]. It confirms the assumption that the order picker's body height influences order pickers' posture during manual material handling and, therefore, on the physical workload [9]. To specify the impact in [9], a laboratory study was conducted. These study results were evaluated by the tool MultipLa. Therefore, the postures adopted by the test subjects were recorded by video and a motion capture system. With the independent evaluation using the "MultipLa" tool, differences in the order pickers' workload due to their posture are analysed. Lastly, in the laboratory study of [9], the optimal picking heights concerning the body postures are identified. Furthermore, the correlation between body height and posture rating points of "MultipLa" was mathematically described using regression functions and correlation coefficients [9]. To elaborate on the simulation results, the "MultipLa" tool has to be described as an algorithm. The tool has never been implemented in a simulation before and is currently implemented as an Excel tool. The integration of the tool in a simulation offers more possibilities than a simple data exchange via Excel and a database.

The analysis of the impact factors indicates that the individual strain can be transferred as mathematical correlations. The next step is the integration of the mathematical correlations into a simulation. The results of this subchapter 3.1 can be consolidated as requirements based on the order picker capability. The next subchapter describes how to design the simulation with the integration of the impact factors.

The impact of dispositional characteristics can be evaluated by multiplicators. Multiplicators are described in the mathematical expression to reflect the impact of these characteristics on the strain. In detail, it is a function of the dispositional characteristics, age, and disabilities of each order picker.

3.2 Design of the agent-based simulation model

The research in ergonomics, including the specified analysis of the impact factors, gives a detailed perspective of manual order picking events. Because of this, an agent-based simulation is chosen. In contrast to the event-discrete simulation, there is a more detailed consideration of the events which take place during order picking. Anylogic software is used for implementation. The simulation aims to develop an agent "human", which integrates the analysed impact factors and estimates them. As a result of the order picking experiments and according to the laboratory study of [9], the simulation model structure can also be logically deduced by beginning at the capabilities of the order picker. The procedure for developing the simulation model is divided into three phases. These are illustrated in figure 2 with a grey background for each phase. A requirement catalogue containing both focuses (impact factors and simulation) has been developed in the first phase. The necessary model parameters are specified in this catalogue. The factors warehouse layout, storage location-allocation, and technical equipment are incorporated into the simulation design as logistics requirements. To further specify, there are simulation requirements (i.e., transforming of all findings into mathematical functions) incorporated into the model.

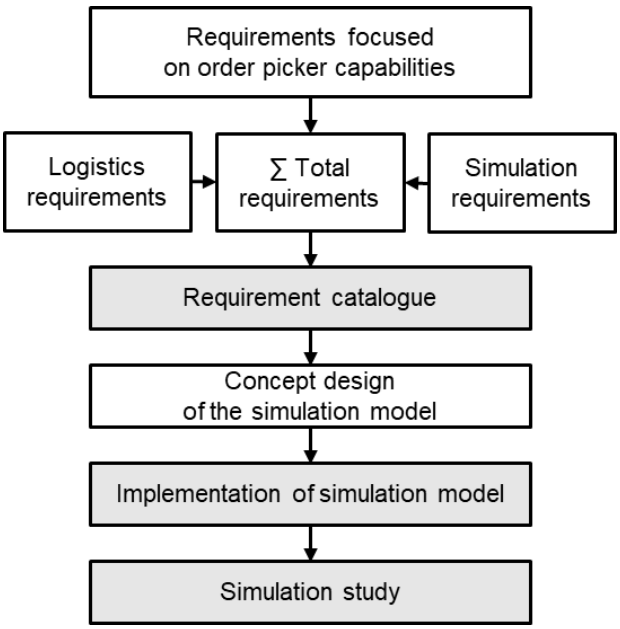

Figure 2. Overview of the design phases.

In the second phase, the agent "human" is developed in such a way that the agent can be implemented in different studies as a result of the concept design. Multiplicators are integrated by a parameter set in the agent. For reproducing the tool "MultipLa" it has to be transformed into an algorithm. In the last phase, the agent is integrated into a simulation study for running the simulation experiments. The experiment results are indicators for defining the impact of human capabilities in manual order picking. The evaluation of the impact and the methods for improvement are subjects of further research.

4 Conclusion

The developed agent "human" offers the possibility to simulate human capabilities and the resulting strains in different scenarios using an agent-based simulation. Before running the simulation study, the impact factors conducting the human capabilities in the individual strain in manual order picking are defined and the framework for the simulation study is described. The simulation studies' results should display indicators that can rate and differentiate the impact factors.

In further studies, a capability-based and employee-related assignment of picking orders could also be implemented to estimate physical strain prevention in manual order picking. By including a constant total workload of all order pickers combined, individual physical strain should be reduced to a minimum.

References

1. R. de Koster, T. Le-Duc, K.J. Roodbergen: Design and control of warehouse order picking: a literature review. In: *European Journal of Operational Research*, S. 481 – 501, (2007).

2. M. Calzavara, C.H. Glock, E.H. Grosse, F. Sgarbossa: An integrated storage assignment method for manual order picking warehouses considering cost, workload and posture. In: *International Journal of Production Research*, S. 2392 – 2408, (2019).

3. T. Franzke, E.H. Grosse, C. H. Glock, R. Elbert: An investigation of the effects of storage assignment and picker routing on the occurrence of picker blocking in manual picker-to-parts warehouses. In *International Journal of Logistics Management vol. 28 841–863* (2017).

4. M. Matusiak, R. de Koster, J. Saarinen: Utilizing individual picker skills to improve order batching in a warehouse. In: *European Journal of Operational Research*, S. 888 – 899 (2017).

5. E.H. Grosse, C.H. Glock, M.Y. Jaber, W.P. Neumann: Incorporating human factors in order picking planning models: framework and research opportunities. In: *International Journal of Production Research*, S. 695 – 717, (2015).

6. F. Sgarbossa, E.H. Grosse, W. P. Neumann, D. Battini, C. H. Glock: Human factors in production and logistics systems of the future. In: *Annu. Rev. Control 49*, 295–305 (2020).

7. W. Rohmert: Ergonomics: Concept of work, stress and strain. In: *International Review of Applied Psychology*, (1986).

8. K. Schaub, M. Bierwirth, M. Kugler, R. Bruder: MultipLa – a tool for the combined overall estimation of various types of manual handling tasks. In. *Work*. Supplement, Vol. 41, p4433-4435. 3p. (2012).

9. T. Steinebach, J. Wenzel, J. Wakula, R. Elbert: The human height as an input parameter for a capability-based order assignment in manual order picking. In: *Arbeit HUMAINE gestalten, GfA Frühjahreskongress 2021, Bochum, GfA-Press, Dortmund,* (2021).