DOI: 10.2195/lj_Proc_stinson_en_201610_01
URN: urn:nbn:de:0009-14-44758

Experimental analysis of manual order picking processes in a Learning Warehouse

Experimentelle Analyse von manuellen Kommissionierprozessen im LernLager

Matthew Stinson
Karl-Heinz Wehking

Institut für Fördertechnik und Logistik (IFT)
Universität Stuttgart

In this paper we discuss the necessity of experimental analysis of manual order picking processes. Next, we describe the design and realization of the Learning Warehouse (DE: LernLager) at the IFT of the University of Stuttgart, followed by initial results of subject testing. The subject testing demonstrates the ability of researchers to analyze individual order picking time components.

[Keywords: order picking, Learning Warehouse, learning processes, person to stock]

In dieser Veröffentlichung wird die Notwendigkeit der experimentellen Analyse von manuellen Kommissionierprozessen behandelt. Anschließend wird die Inbetriebnahme des LernLagers am IFT der Universität Stuttgart beschrieben. Zum Schluss werden erste Ergebnisse von Probandenversuchen im LernLager vorgestellt mit Fokus auf der Analyse individueller Zeitkomponenten in der Kommissionierung.

[Schlüsselwörter: Kommissionierung, LernLager, Modelllager, Lernprozesse, Person-zur-Ware]

1 INTRODUCTION

Manual person-to-stock order picking remains the dominant form of order picking despite rapidly advancing automation technologies [Str 05, Fae 16]. The prevalence of manual activities is due in part to the human capability to quickly adapt to dynamic conditions in which wide ranges of heterogeneous products must be reliably and efficiently handled. Also, fluctuating order volumes are more easily managed by humans than automated systems, as the latter must generally be configured for peak demand [Gue 03, Hom 03]. Through the use of temporary workers during peak demand, for example during the holiday season for online retailers, a distribution center's capacity can be continuously adjusted in order to meet current demands. Manual order picking systems that operate according to the preson-to-stock principle are associated with high personnel costs; however, investment costs are minimal in comparison to automated systems [Hom 11]. Based on discussions with numerous suppliers and operators of warehouse technology, the IFT estimates that a small warehouse with a fully functional IT-infrastructure can be realized in an existing building at an initial investment cost of several hundred thousand Euros.

Studies on order picking are typically limited to analyses of business data. These data can be quite extensive in terms of the number of process cycles observed and the sampling timeframe, though less they are generally less transparent than data collected in a laboratory environment. Experimental analysis of intralogistics processes represents a new approach to understanding and optimizing the human's working conditions and performance in production and distribution logistics environments. In utilizing a laboratory setting, various influencing factors can be isolated and precisely adjusted in order to attain more precise results than can be produced using industry data. [Sti 16] Due to the high cost and effort required for experimental investigation of manual processes, few such studies have been performed with relation to manual order picking. Corresponding publications include [Gro 15], [Gro 13], [Gue 09] and [Gue 15].

2 REALIZATION OF A LEARNING WAREHOUSE FOR EXPERIMENTATION

In order to collect data relevant to practitioners, the IFT created a laboratory environment known as the Learning Warehouse (DE: LernLager) for the analysis of manual order picking processes. The Learning Warehouse implements modern shelving and picking technologies which are readily available on the current market. The Learning Warehouse features redundant picking technologies that can utilized independently or parallel to one another. The state of the art warehouse management software (WMS) WAMAS 5 from SSI Schäfer allows various picking configurations, for example single- and multi-order picking, different scan processes and complex navigation strategies.

The Learning Warehouse comprises a floor surface area of approximately 120 quadratic meters with three

DOI: 10.2195/lj_Proc_stinson_en_201610_01
URN: urn:nbn:de:0009-14-44758

picking aisles. Using a relatively small picking cart, realistic working conditions can be simulated. The Learning Warehouse also features a WLAN-based tracking system with additional infrared beacons in order to precisely track the paths of subjects, the picking cart and other objects. An overview of the Learning Warehouse and a photo of one aisle are provided in Figures 1 and 2.

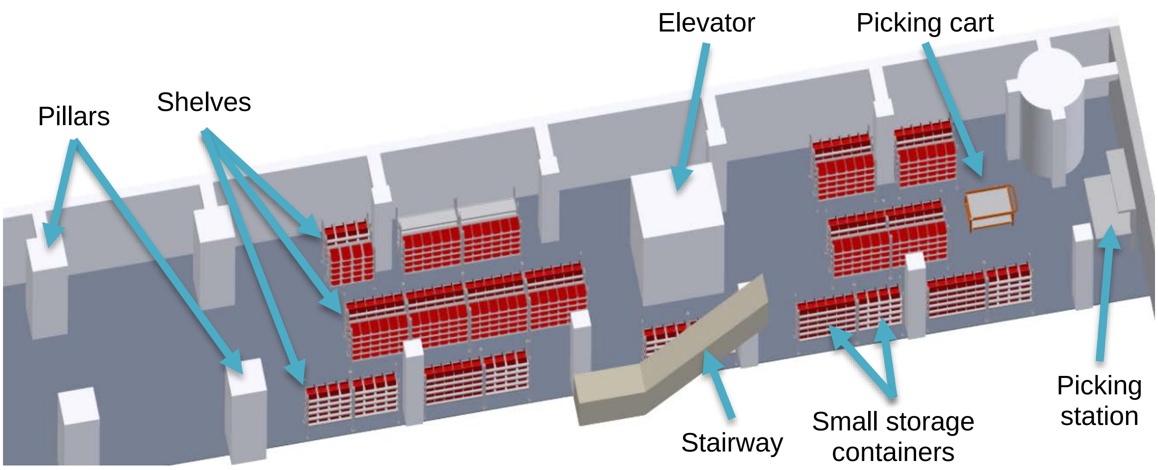

Figure 1. Layout of the Learning Warehouse

Figure 2. One of three picking aisles in the Learning Warehouse

2.1 Information System

Orders picked in the Learning Warehouse are typically generated based on an experimentation matrix. Orders are automatically converted either directly into picking orders or picking order groups if multi-order picking is enabled. Alternatively, a physical picking list can automatically printed. Thus, orders can be assigned to subjects in the Learning Warehouse either as a printed list (see Figure 3) or digitally via WLAN onto one of the following the four end devices: a handheld barcode scanner, a headset, dataglasses or a pick-by-light system. The latter of these systems requires orders to be entered directly into it, as it is not connected to the warehouse management system.

A typical picking process using the handheld barcode scanner requires that the subject scan a barcode label at the active storage location at the start and end of each order line in order to minimize picking mistakes as well as to create a sufficient number of time stamps for analysis without disrupting the normal picking process. The four mobile end devices featured in the Learning Warehouse are a two-dimensional handheld barcode scanner from Datalogic with the model name Falcon X3 (see Figure 4), a pick-by-voice mobile PC and headset of the Lydia series from Topsystem (see Figure 5) and a pick-by-vision system based on Google Glass from Picavi (see Figure 6).

Figure 3. Pick-by-line with physical list

Figure 4. Pick-by-scan with handheld barcode scanner

DOI: 10.2195/lj_Proc_stinson_en_201610_01
URN: urn:nbn:de:0009-14-44758

Figure 5. Pick-by-voice

Figure 6. Pick-by-vision

Additionally, most storage locations are equipped with pick-by-light technology from SSI Schäfer. This system allows orders to be picked without having to carry an order list and/or device while working. The system also allows for items to be picked without the picker having knowledge of the coordinate system used in the warehouse. Using pick-by-light, the items which need to be picked are denoted with a lit red LED and a number next to the indicator which denotes the number of picks required. An aisle of the Learning Warehouse which is fully equipped with pick-by-light is shown in Figure 7.

Figure 7. Pick-by-light

2.2 Material Flow System

Approximately 3,000 small articles were provided by L'Oréal for picking in the Learning Warehouse. In contrast to real world order picking situations, the articles generally do not leave the Learning Warehouse. Instead, all completed orders are checked for accuracy and restocked. Thereby, articles are presented to the pickers statically and decentralized in approximately 1.100 storage locations in small picking containers from SSI Schäfer, which are held in standard shelving equipment from the same company. Each picking container is marked with its coordinates, which are expressed by barcode and in Arabic numbering. Additionally, a two-digit control code is printed on the same label for use with the pick-by-voice system.

Articles are extracted from the containers manually without the help of machinery. Depending on which picking technology is being used, the number of picks for a given order line and the dimensions of the items being picked, the picker may extract items using one or two hands. Picked items are generally placed in small collection containers on a picking cart and transported either individually or in batches to an order turnover station.

A WLAN-based tracking system allows the movements of pickers and the picking carts to be precisely recorded. Thereby, the picker wears a small WLAN card as he or she works and a second card is placed on the picking cart. The WLAN tracking results are verified by conferring the scan records of a redundant, integrated infrared identification system. The tracking system allows for the precise recording of the pickers' individual navigation strategies, which are not fully identifiable based on the time stamp data alone.

2.3 Organization System

The build organization in the Learning Warehouse is generally single-zoned due to its relatively small size. It could, however, be divided into different areas in order to allow, for example, zone-parallel order picking using pick-by-light. Within the scope of the process organization, sequential and parallel picking of orders is possible. An optimization of the order steering can be simulated within the scope of the processing organization.

3 Initial Analysis of Individual Picking Time Components after Initial Subject Testing

The IFT conducted a small study using 20 subjects who picked in the Learning Warehouse using a hand scanner. Each subject was assigned the same 18 picking orders, whose summative MTM-calculated work volume equals between approximately 45 and 40 minutes, depending on whether single- or multi-order picking was implemented, respectively. Subjects 1 through 11 utilized single-order picking while subjects 12 through 20 utilized multi-order picking with order groups of two. The total order picking time was divided into three components: base time, travel time and extraction time.

DOI: 10.2195/lj_Proc_stinson_en_201610_01
URN: urn:nbn:de:0009-14-44758

The implemented picking process foresees the scanning of each relevant storage location once before the extraction of the required number of items and once following their extraction. The time which passes between these two barcode scans is referred to as the extraction time. The subjects are not shown the number of items required until the initial barcode scan and thus cannot first extract the item and then scan the storage location barcode twice. Subjects are discouraged from scanning the barcodes twice before extraction, as the number of required items is shown only between both scans. Following the completion of an order line, the subject is shown the next relevant storage location. The time which passes before this barcode is read is interpreted as travel time and includes the return travel time to the picking base. The base time encompasses all activities performed between the confirmation of the last order line of picking order *n* and the initiation of the first position of order *n+1*. The observed picking process and the corresponding time stamps are illustrated in Figure 8.

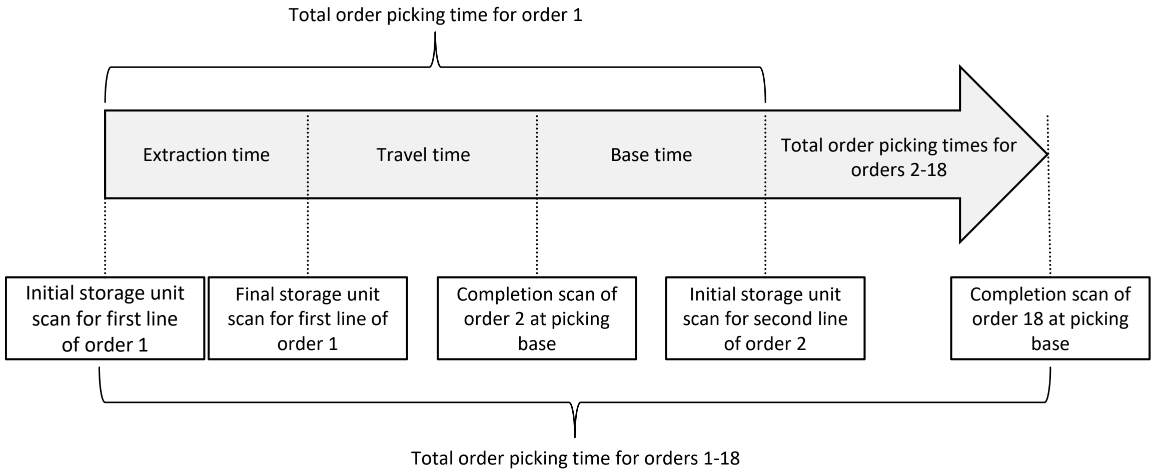

Figure 8. Picking process in the Learning Warehouse using scanner and single-order picking

The time stamps recorded within the scope of the study were evaluated in order to calculate the total order times and individual time components for each subject. The results are shown in Figure 9.

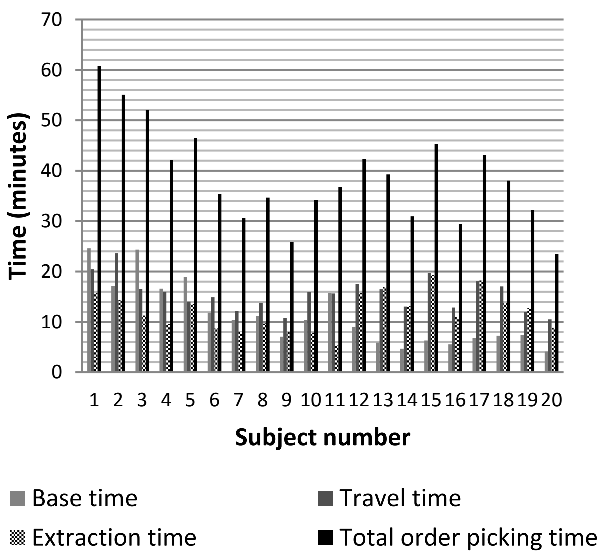

Figure 9. Picking times of subjects in the Learning Warehouse

The initial 20 subjects include 15 students, four employees and one retiree. The average total order picking time was 38.9 minutes. The average picking time components vary respective to one another between subjects, though the base time is generally the smallest time component, especially for subjects who worked using multi-order-picking and thus visited the picking base nine times instead of 18 times. The average time components of all subjects are shown in Figure 10.

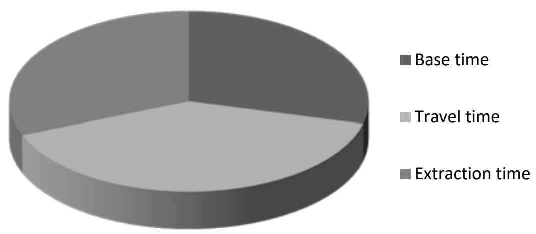

Figure 10. Average picking time components

The largest standard deviation was observed among the base times at 6.1 minutes and might be explained by the tendency of the older subjects to struggle with operating the barcode scanner. The standard deviations for travel time and extraction time were 3.3 and 3.8 minutes, respectively. Following each subject test, the picking quality was assessed. Thereby, each mistake was classified based on [11] and connected to an order line as well as to an additional order if, for example, an item was placed in the incorrect collection box during multi-order picking. The recorded picking mistakes are summarized in Table 1.

Table 1: Picking mistakes in the Learning Warehouse

Mistake type	Number of order lines affected	Absolute number of incorrect, neglected and/or unnecessary picks
Wrong item	3	3
Wrong amount	16	39
Item left out	4	10
Wrong collection box	18	32

4 SUMMARY AND OUTLOOK

As additional subject testing takes place in the Learning Warehouse, a determination will be made as to which variables most closely correspond to various aspects of picking performance, including navigation, handling of items and picking quality. These variables are either picking order-, warehouse environment- or person-based. Following the described analysis, measures will be taken in order to optimize the performance of a new group of subjects picking the same 18 orders in the Learning Warehouse. Based on our initial findings, we hypothesize that single-order picking by subjects without prior warehouse experience will reduce the number of mistakes, especially the number of wrong collection box mistakes, to the extent that its base- and travel time advantages will be outweighed. Future experimentation will also consider the additional picking technologies described in section 2 as well as various training concepts.

REFERENCES

[Str 05] F. Straube, H.-C. Pfohl, W. Günthner, W. Dangelmaier, Trends und Strategien in der Logistik: Ein Blick auf die Agenda des Logistik-Managements 2010, Dt. Verkehrs-Verl., Hamburg, 2005.

[Fae 16] N. Fähnrich, M. Stinson, K.-H. Wehking, LernLager für die Kommissionierung: Praxisnahe Bedingungen für die Untersuchung verschiedener manueller Tätigkeiten, Hebezeuge Fördermittel (2016) 20–21.

[Gue 03] H. Günther, H. Tempelmeier, Produktion und Logistik, 5th ed., Springer Verlag, Berlin, 2003.

[Hom 03] M. ten Hompel, T. Schmidt, Warehouse Management: Automatisierung und Organisation von Lager- und Kommissioniersystemen, Springer, Berlin [u.a.], 2003.

[Hom 11] M. ten Hompel, V. Sadowsky, M. Beck, Kommissionierung: Materialflusssysteme 2 Planung und Berechnung der Kommissionierung in der Logistik, Springer, Heidelberg, 2011.

[Sti 16] M. Stinson, F. Müller, D. Korte, K.-H. Wehking, Lernkurven in manuellen Person-zur-Ware-Kommissioniersystemen (LeiKom): Schlussbericht, available at http://www.bvl.de/files/429/523/Abschlussbericht_LeiKom.pdf (accessed on February 18, 2016).

[Gro 15] E.H. Grosse, Human factors in order picking systems: A framework for integrating human factors in order picking lanning model with an in-depth analysis of learning effects, B+G Wissenschaftsverl, Würzburg, 2015.

[Gro 13] E.H. Grosse, C.H. Glock, M.Y. Jaber, The effect of worker learning and forgetting on storage reassignment decisions in order picking systems, Computers & Industrial Engineering 66 (2013) 653–662.

[Gue 09] W. Günthner, N. Blomeyer, R. Reif, M. Schedlbauer, Pick-by-Vision: Augmented reality unterstützte Kommissionierung, Lehrstuhl für Fördertechnik Materialfluss Logistik, Garching, 2009.

[Gue 15] W. Günthner, M. Klevers, H. Mandl, M. Sailer, GameLog - Gamification in der Intralogistik, Lehrstuhl für Fördertechnik Materialfluß Logistik (fml) TU München, Garching b. München, 2015.

Matthew Stinson, M.Sc., MBE is head of the Department of Logistics at the Institute for Materials Handling and Logistics (IFT) of the University of Stuttgart. He studied Economics and Business, German, Industrial Engineering and Logistics Management at Hendrix College, Pforzheim University and the University of Stuttgart.

Address:
Holzgartenstraße 15b, 70174 Stuttgart, Germany

Phone: +49 711-685-83743, Fax: +49 711-685-83769,
E-Mail: matthew.stinson@ift.uni-stuttgart.de

Prof. Dr.-Ing. Dr. h. c. Karl-Heinz Wehking is head of the Institute for Materials Handling and Logistics (IFT) of the University of Stuttgart. He studied Mechanical Engineering and obtained his doctoral title at the University of Dortmund.

Address:
Holzgartenstraße 15b, 70174 Stuttgart, Germany

Phone: +49 711-685-83440, Fax: +49 711-685-83769,
E-Mail: wehking@ift.uni-stuttgart.de