

## Work Characteristics in Logistics 4.0: Conceptualization of a qualitative assessment in order picking

Sven Winkelhaus\*, Eric H. Grosse\*\*

\**Institute of Production and Supply Chain Management, Technische Universität Darmstadt, Hochschulstrasse 1, 64289 Darmstadt, Germany (e-mail: [winkelhaus@pscm.tu-darmstadt.de](mailto:winkelhaus@pscm.tu-darmstadt.de))*

\*\**Juniorprofessorship of Digital Transformation in Operations Management, Saarland University, P.O. 151150, 66041 Saarbrücken, Germany (e-mail: [eric.grosse@uni-saarland.de](mailto:eric.grosse@uni-saarland.de))*

**Abstract:** Logistics 4.0 is an emerging phenomenon, where new digital technologies are used to fulfil increasing demands of delivering individualized products against high cost pressure and fast delivery times. Within this development, human factors should not be neglected, since they will remain an important aspect of process efficiency and business success. One logistics process that has undergone a major transformation within Logistics 4.0 regarding manual human work is warehouse order picking. However, the implications of increasing digitalization on human workers in order picking are not yet fully understood. Hence, this contribution grounds on a qualitative assessment of work characteristics in order picking and conceptualizes possible influences of the digital transformation on order pickers. These conceptual interrelations enable to design future workplaces that allow higher job satisfaction, motivation, quality and performance of work as well as lower turnover intentions.

Copyright © 2020 The Authors. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0>)

**Keywords:** Work characteristics, Job satisfaction, Job Motivation, Order picking, Warehouse, Logistics, Digital transformation, Digitalization, Logistics 4.0

### 1. INTRODUCTION

Logistics activities are of great importance in co-determining companies' efficiency and productivity. Low safety stocks and fast delivery are well known targets for companies that are challenged in the fourth industrial revolution and its emerging phenomenon Logistics 4.0.

#### 1.1 Logistics 4.0

In the fourth industrial revolution, industry and logistics undergo a great transformation to meet new requirements of individualized products, shortening lifecycles, global competition and the need for sustainability (Kagermann, Wahlster, and Helbig 2013, Lasi et al. 2014, Hofmann and Rüsçh 2017). For example, individualized products need individual ways through the factory and unique packaging, and lead to unstable demands and a high variability of primary products. These paradigmatic changes add new complexity and challenge the efficient satisfaction of customer demands. Dealing with these demands, logistics transforms in the undergoing fourth industrial revolution towards Logistics 4.0, which can be defined as “*the logistical system that enables the sustainable satisfaction of individualized customer demands without an increase in costs and supports this development in industry and trade using digital technologies*” (Winkelhaus and Grosse 2020). Hence, Logistics 4.0 incorporates new technological applications that enable the efficient satisfaction of such customer demands. The Internet of Things (IoT), artificial intelligence (AI), or cyber-physical systems (CPS) are just three examples of technologies potentially meeting

these new requirements (Hofmann and Rüsçh 2017, Kagermann, Wahlster, and Helbig 2013, Lu 2017). However, it can be noted that Logistics 4.0 considers both, digitalization and automatization, as well as the consideration of humans and how they will work in future logistics workplaces and interact with technologies.

#### 1.2 Human Factors in Logistics

Logistics processes and tasks are still characterized by a high share of manual human work (Michel 2016, Behnisch et al. 2017). Since the tasks in logistics will change in the development towards Logistics 4.0, characteristics of human work will be transformed, too, which can have a significant influence on the system's performance. Human factors is defined as “*the scientific discipline concerned with the understanding of interactions among humans and other elements of a system [...] in order to optimize human well-being and overall system performance*” (International Ergonomics Association 2019).

Within logistics, especially order picking is a labor-intensive and costly process (Grosse, Glock, and Neumann 2017), which is why considering human factors in order picking has been in the scope of researchers (e.g. Grosse et al. (2015), Glock et al. (2017), Grosse et al. (2017), Grosse, Glock, and Neumann (2017), Grosse et al. (2016)). However, the interrelation of order picking, human work, and the digital transformation is still under-researched. This is remarkable, because it is widely assumed that humans will remain a significant part in Logistics 4.0 (Kagermann, Wahlster, and Helbig 2013, Kadir, Broberg,

and Conceicao 2019) and thus will co-determine companies' success, also in managing the challenges of the digital transformation. Overall, within the process of changing work tasks and work environments in Logistics 4.0, work characteristics are transformed, too, which might influence job satisfaction, motivation or turnover intention.

### 1.3 Work Characteristics

A well-known and often validated theory of work characteristics is the so-called Job Characteristics Model (JCM) (Hackman and Oldham 1974, 1975, Loher and Noe 1985). In this model, the authors hypothesized an influence of five essential characteristics on work outcomes, i.e. skill variety, task identity, task significance, autonomy, and feedback from the job, which are moderated via three critical psychological states leading to work outcomes like job satisfaction and motivation. In addition to that, other job outcomes are found to be impacted by the characteristics like turnover intention, quality of work and performance (Loher and Noe 1985, Astry and Daugherty 2003, Morris and Venkatesh 2010).

The JCM was used and refined several times (Morris and Venkatesh 2010, Ang and Slaughter 2001), and also inspired the development of the Work Design Questionnaire, which is based on the hypothesis of the JCM, but enlarges the work characteristics with possible influences in four categories: task characteristics that are equal to the characteristics defined in the JCM, knowledge characteristics, social characteristics and context characteristics (Morgeson and Humphrey 2006). Overall, Morgeson and Humphrey (2006) identified 18 characteristics of relevance.

### 1.4 Research Objective

As already hypothesized in a theoretical study, Waschull et al. (2020) found that CPS will have a significant impact on work characteristics. However, empirical results are still scarce (Kadir, Broberg, and Conceicao 2019, Korner et al. 2019). Based on the data of a qualitative assessment of work characteristics in enterprises with different Logistics 4.0 maturity levels (Winkelhaus and Grosse 2019), this study aims at conceptually answering the following research question (RQ):

**RQ:** Which influences do Logistics 4.0 technologies have on work characteristics of order pickers?

The rest of the article is structured as follows: First, the results of a literature review are presented. Second, data of an empirical study is used to assess the changing work characteristics of order pickers in Logistics 4.0. Third, these results are conceptualized to examine the impacts of Logistics 4.0 on important characteristics of order picking workplaces. Afterwards, this framework is discussed and limitations are outlined, before the article is concluded.

## 2. LITERATURE REVIEW

The literature review shows that both aspects, work characteristics in logistics, as well as work characteristics in the digital transformation, Industry 4.0 and Logistics 4.0, have attracted only limited attention in research so far.

### 2.1 Work Characteristics in Logistics

Most studies in this field of research primarily focused on work characteristics of specific professions like truck drivers or warehouse employees (Min 2007). There are also some studies that attempted to measure job satisfaction but without focus on factors that trigger or inhibit it. This observation was already outlined by Maloni et al. (2017). Other studies focused on special organizational aspects related to lean production (de Haan, Naus, and Overboom 2012) or the role of supervisors and employers (Ellinger, Ellinger, and Keller 2005, Maloni et al. 2019, Chhetri et al. 2018). However, a broad focus on work characteristics in logistics is missing, which is why the focus of the next section generally lies on work characteristics in the digital transformation, aiming to transfer knowledge of these studies.

### 2.2 Work Characteristics in the Digital Transformation

There are only few studies that directly deal with work characteristics in the digital transformation. These studies often apply survey methods and investigate for example the outcomes of the implementation of an IT-system like ERP (Morris and Venkatesh 2010, Venkatesh, Bala, and Sykes 2010) on work characteristics, or which influences organizational aspects could have on this process (Mitchell et al. 2012). Especially relevant in this context is the study of Bala (2013), who investigated the effects of IT-enabled SCM processes on work characteristics. Main findings were that the implementation influenced process characteristics and especially process rigidity and complexity led to perceived negative outcomes.

Studies that investigated automation technology empirically are scarce in connection with work characteristics. de Witte and Steijn (2000) for example showed possible effects of automation on work characteristics and underemployment. A theoretical study provided by Waschull et al. (2020) considered three work characteristics, i.e. job complexity, job autonomy and skill variety and examined on a conceptual basis, which influences the implementation of CPS could have on these characteristics. Current research on future human work, e.g. according to the "Operator 4.0" paradigm (see e.g. Romero et al. (2016)) does not focus on human factors in depth in most cases and work characteristics remain notably unaddressed.

Summing up, there seems to be a clear research gap in the intersection of logistics work, work characteristics and the digital transformation of logistics. Moreover, the review hints at possibly relevant interrelations.

### 3. QUALITATIVE STUDY

To gain insights into the perceived characteristics of order picking workplaces, data of a qualitative study employing semi-structured interviews is used (Winkelhaus and Grosse 2019), as this method is especially relevant to gain insights into a topic without preconception (Grosse et al. 2016). In the study of Winkelhaus and Grosse (2019), 13 logistics workers in a total of six companies in five different industries were interviewed, who all have had experience as order pickers or warehouse supervisors. The interview guide was used for data collection covered all 18 work characteristics examined by Morgeson and Humphrey (2006) in open and neutral questions. In the work at hand, we re-examine this qualitative data to generate deeper insights especially into perceived changes of work characteristics for order pickers in Logistics 4.0, which extends the analyses of Winkelhaus and Grosse (2019).

The observed case companies have different levels of Logistics 4.0 maturity, which was considered in the analysis to allow the derivation of impacts of different degrees of digitalization and automation on the perceived work characteristics. The Logistics 4.0 maturity was assessed based on the maturity model developed by Asdecker and Felch (2018), which includes digital as well as automation technologies on different maturity levels for every task in the logistics process. Therefore, the workplaces were analyzed on-site. The tasks performed were evaluated according to the characteristics indicated for each level and task according to the maturity index. The calculated overall index of every workplace served as an indicator of the maturity. For a more precise description of the maturity model, the reader is referred to Asdecker and Felch (2018).

Overall, three groups were identified with comparable characteristics. Three out of the 13 interviewees work completely analogue and manual in the warehouse, whereas six interviewees work in a more digitalized environment and mid to high Logistics 4.0 maturity. Another four interviewees interact with a high share of automation technology in their workplaces, especially automated storage and retrieval systems. These cases were assessed to have a high Logistics 4.0 maturity according to the applied maturity model where both automation technology and accompanying digital technologies are considered towards Logistics 4.0.

#### 4. WORK CHARACTERISTICS FOR ORDER PICKERS IN LOGISTICS 4.0

The analysis of the interview data revealed two major effects and several more detailed effects of Logistics 4.0 on human work in order picking. The two major effects relate to the impact of automation and digitalization on perceived work characteristics based on the usage of these technologies. Broadly speaking, digitalization, like pick-by-technologies and support from IT-systems, facilitates a more efficient and effective work performance compared to manual and analogue workplaces. This leads to free time, which was, in the case companies, often spent by the workers to support prior or following tasks leading to a better understanding of the relevance of work and higher task variety. Compared to

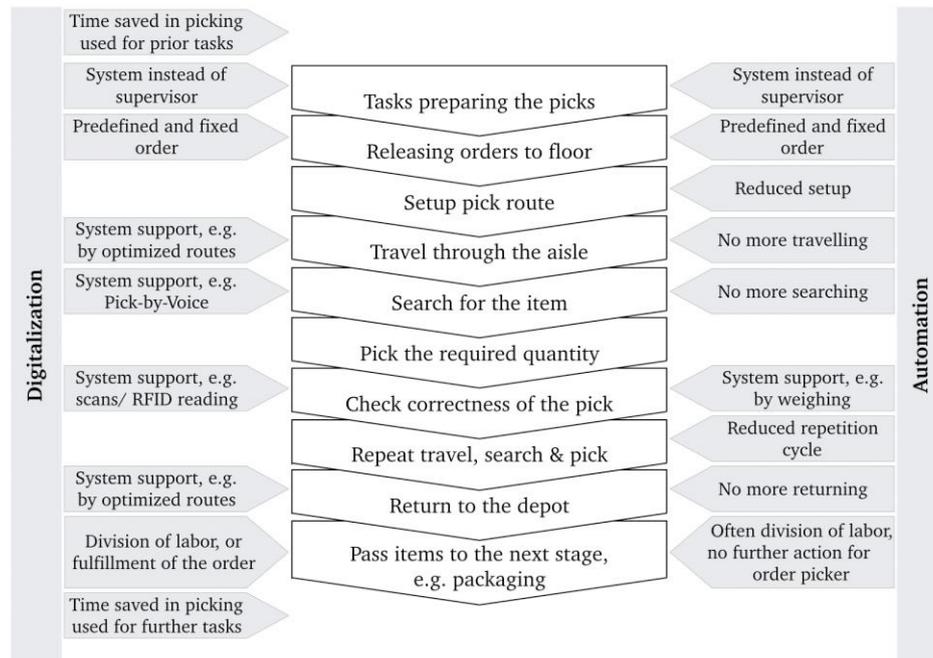
analogue workplaces, technologies standardize work and support the workers in information processing tasks. However, there is a shift in the needed knowledge from product and process knowledge to knowledge about how to handle the used systems best. Concerning social characteristics and context characteristics, digitalization does not show major influences, since these aspects are only rarely touched by the systems used in the case companies.

This differs regarding automation technology. These systems have strong perceived influences especially on contextual characteristics like ergonomics or physical demands. Knowledge characteristics are, however, reduced, since the cases showed a significant reduction of tasks performed and interaction with the necessarily used digital components of the automated storage and retrieval systems. Since the automated systems were described as complex, often only supervisors and IT-personnel solve problems, which also had an effect on the perceived work autonomy. Overall, this led to a decrease of perceived identity, significance, and task variety.

Our findings allow to develop a conceptual framework that outlines the examined directions of the assessment. Figure 1 illustrates the effects of automation and digital technologies on the order picking tasks on the individual task level. The basic order picking process steps are based on the assumptions of de Koster, Le Duc, and Roodbergen (2007), and Tompkins et al. (2010), which were also observed in the case companies. For example, since the automation technology in a case company worked as an automated storage and retrieval system, the order pickers do not have to walk through the aisles to pick the items. On the other hand, due to digitalization, the interviewees reported that e.g. pick-by-voice systems eased the tasks performed on a perceptual level. Saved time was found to be used for supporting other tasks. Of course, these interrelations can only be drawn based on the cases observed and just work as an explorative example of interrelations.

These interrelations are further conceptualized as shown in Figure 2. In this figure, not the process is in the focus, but the mediating mechanisms like standardization or the reduction of social interaction. In turn, this affects not only the process, but also the work characteristics of the order pickers. The influence of digital and automation technologies on perceived work characteristics, as examined in the exploratory study, is displayed via “+”, meaning an improvement of the characteristic, “o” when there is no or only little effect or the direction is neither positive nor negative, and “-”, which means that there is a deterioration of the work characteristic. Due to the diverse influences that the mechanisms have on work characteristics, not the explicit interrelations are shown, but in general, which mechanisms have been identified and which work characteristics outcomes have been found. The characteristics then lead to the overall effects on job satisfaction, turnover intention, motivation etc.

This framework might be seen as a first step to develop a more holistic understanding of the immediate effects digitalization and automation have on order picking, and how these processes then affect the order pickers’ work characteristics. For example, digitalization might enable the standardization of



**Figure 1: Influences of digitalization and automation on the order picking process.**

processes, which leads to the reduction of effort spent for some tasks and increases the quality and productivity by checks of the performed pick. This was also found to lead to an enlargement or enrichment of tasks, the support of co-workers, or added new tasks that deal with the equipment and system handling. This nevertheless could also inhibit autonomy, since process rigidity is emphasized. However, we stress again that this is not a fixed and determined direction, but the outcome of a qualitative assessment in six case companies. We would like to note that, of course, e.g. automation systems might also be designed to allow for an improvement of most of the characteristics, but it was not found within the interview data. Based on the qualitative assessment, the different identified directions are drawn, but other paths are possible. Furthermore, the developed framework is used to identify possible interrelations especially for warehouse order pickers, but it is usable for every type of workplace and can be adapted therefore.

## 5. DISCUSSION AND LIMITATIONS

The framework described enables the design of workplaces in order picking in two directions: On the one hand, it can be used as an analysis instrument for practitioners, when digital or automation technologies are planned to be implemented. Then, the possible outcomes for warehouse employees can be evaluated and possible organizational changes can be adopted in the pre-implementation phase. For example, order pickers could be taught to deal with certain problems on their own to increase perceived autonomy. Moreover, the investment decision can be influenced, e.g. if there is a more flexible or human friendly system, it could justify an additional price.

On the other hand, it could be used in enterprises where the employees express that single or multiple work characteristics are suboptimal or supervisors find potential improvements. For example, high physical demands or low perceived meaningfulness of work could lead to bad work results or high

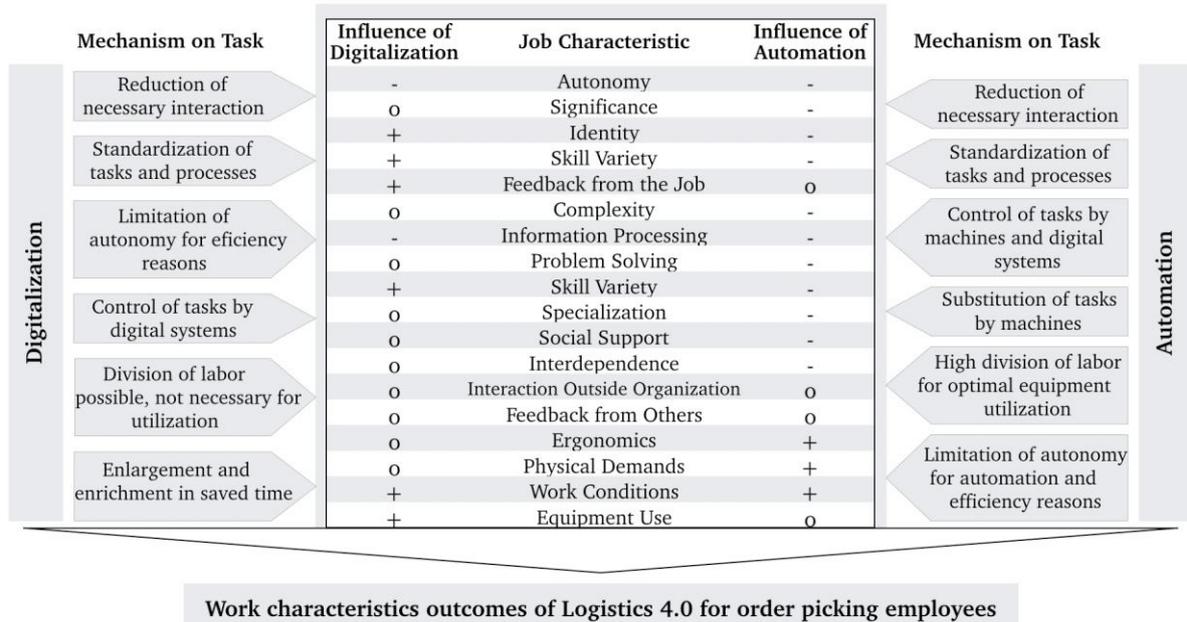
absenteeism. In these cases, digital and automation technologies might be used to improve these work characteristics. Finding the best technology for these reasons is supported by the conceptualization of the study's results, since it also allows a 'reverse' path.

Moreover, the study shows remarkable directions for some work characteristics, because one might assume that e.g. feedback from the job and feedback from others could be triggered easily with digital technologies. However, this was not found within the case companies, although of course, there are systems that support such feedbacks. These systems are nevertheless not the standard in all applications according to our study's results.

This also hints at some limitations of the insights gained from the qualitative approach used for this conceptualization. Although the sample shows a high share of similar answers, the number of interviewees per maturity level is limited. Moreover, only companies in Germany were included in the case-dataset we used, which could have led to location-based effects. However, this study can be seen as an explorative contribution that highlights insights on Logistics 4.0 that are currently observable in practice.

## 6. CONCLUSIONS

Logistics 4.0 is an increasing phenomenon that will change the way logistics work is performed in the future (Winkelhaus and Grosse 2020). Although it is often considered from a technological viewpoint, human factors are essential in logistics tasks and will remain a significant determinant for business success and customer satisfaction, in particular with regard to the labor-intensive order picking tasks in internal logistics. Hence, this study contributes to the literature by gaining insights into the impact that digital and automation technologies currently have on order picking employees. It became obvious that some aspects of currently implemented



**Figure 2: Impacts of digitalization and automation technologies on processes and work characteristics.**

systems that are at least partly manual, do not improve work characteristics that are relevant for job satisfaction and might even inhibit performance. Aiming for social sustainability, human factors and possible outcomes of technology implementation on the work characteristics should be considered early in the decision processes and standardized feedback loops from the workers to the management are necessary.

Based on these findings, a future “Order Picker 4.0” could be conceptualized that is able to perform highly customized and efficient work at a workplace that enables a high job satisfaction. Future research could, for example, deepen these findings by collecting more data until saturation in companies reflecting every Logistics 4.0 maturity level and different mixes of automation and digital technologies. Moreover, a standardized survey-based analysis could extend this work to achieve quantifiable results.

#### REFERENCES

- Ang, S., and Slaughter, S.A. 2001. "Work Outcomes and Job Design for Contract versus Permanent Information Systems Professionals on Software Development Teams." *MIS Quarterly* 25 (3):321-350.
- Asdecker, B., and Felch, V. 2018. "Development of an Industry 4.0 maturity model for the delivery process in supply chains." *Journal of Modelling in Management* 13 (4):840-883.
- Autry, C.W., and Daugherty, P.J. 2003. "Warehouse Operations Employees: Linking Person-Organization Fit, Job Satisfaction, And Coping Responses." *Journal of Business Logistics* 24 (1):171-197.
- Bala, H. 2013. "The effects of IT-enabled supply chain process change on job and process outcomes: A longitudinal investigation." *Journal of Operations Management* 31 (6):450-473.
- Behnisch, P., Glock, C.H., Grosse, E.H., and Ries, J. 2017. "Auf dem Weg zum Warehouse 4.0?" In *Warehousing 4.0*, edited by C.H. Glock and E.H. Grosse, 53-74. B+G Wissenschaftsverlag.
- Chhetri, P., Gekara, V., Manzoni, A., and Montague, A. 2018. "Productivity benefits of employer-sponsored training." *Education + Training* 60 (9):1009-1025.
- de Haan, J., Naus, F., and Overboom, M. 2012. "Creative tension in a lean work environment: Implications for logistics firms and workers." *International Journal of Production Economics* 137 (1):157-164.
- de Koster, R., Le Duc, T., and Roodbergen, K.J. 2007. "Design and control of warehouse order picking: A literature review." *European Journal of Operational Research* 182:481-501.
- de Witte, M., and Steijn, B. 2000. "Automation, Job content, and Underemployment." *Work, Employment and Society* 14 (2):245-264.
- Ellinger, A.E., Ellinger, A.D., and Keller, S.B. 2005. "Supervisory coaching in a logistics context." *International Journal of Physical Distribution & Logistics Management* 35 (9):620-636.
- Glock, C.H., Grosse, E.H., Elbert, R.M., and Franzke, T. 2017. "Maverick picking: the impact of modifications in work schedules on manual order picking processes." *International Journal of Production Research* 55 (21):6344-6360.
- Grosse, E.H., Calzavara, M., Glock, C.H., and Sgarbossa, F. 2017. "Incorporating human factors into decision support models for production and logistics: current

- state of research." *IFAC-PapersOnLine* 50 (1):6900-6905.
- Grosse, E.H., Dixon, S.M., Neumann, W.P., and Glock, C.H. 2016. "Using qualitative interviewing to examine human factors in warehouse order picking: technical note." *International Journal of Logistics Systems and Management* 23 (4):499-518.
- Grosse, E.H., Glock, C.H., and Neumann, W.P. 2017. "Human factors in order picking: a content analysis of the literature." *International Journal of Production Research* 55 (5):1260-1276.
- Hackman, J.R., and Oldham, G.R. 1974. "The Job Diagnostic Survey: An instrument for the diagnosis of jobs and the evaluation of job redesign projects." *Technical Report No. 4, Department of Administrative Sciences, Yale University*.
- Hackman, J.R., and Oldham, G.R. 1975. "Development of the Job Diagnostic Survey." *Journal of Applied Psychology* 60 (2):159-170.
- Hofmann, E., and Rüscher, M. 2017. "Industry 4.0 and the current status as well as future prospects on logistics." *Computers in Industry* 89:23-34.
- International Ergonomics Association 2019. "Definition and Domains of Ergonomics." <https://www.iea.cc/whats/>.
- Kadir, B.A., Broberg, O., and Conceicao, C.S.d. 2019. "Current research and future perspectives on human factors and ergonomics in Industry 4.0." *Computers & Industrial Engineering* 137.
- Kagermann, H., Wahlster, W., and Helbig, J. 2013. Recommendations for implementing the strategic initiative Industrie 4.0, Securing the future of German manufacturing industry, Final report of the Industrie 4.0 Working Group.
- Korner, U., Muller-Thur, K., Lunau, T., Dragano, N., Angerer, P., and Buchner, A. 2019. "Perceived stress in human-machine interaction in modern manufacturing environments-Results of a qualitative interview study." *Stress Health* 35 (2):187-199.
- Lasi, H., Kemper, H.-G., Fettke, P., Feld, T., and Hoffmann, M. 2014. "Industry 4.0." *Business & Information Systems Engineering* 4:239-242.
- Loher, B.T., and Noe, R.A. 1985. "A Meta-Analysis of the Relation of Job Characteristics to Job Satisfaction." *Journal of Applied Psychology* 70 (2):280-289.
- Lu, Y. 2017. "Industry 4.0: A survey on technologies, applications and open research issues." *Journal of Industrial Information Integration* 6:1-10.
- Maloni, M.J., Campbell, S.M., Gligor, D.M., Scherrer, C.R., and Boyd, E.M. 2017. "Exploring the effects of workforce level on supply chain job satisfaction and industry commitment." *The International Journal of Logistics Management* 28 (4):1294-1318.
- Maloni, M.J., Gligor, D.M., Cheramie, R.A., and Boyd, E.M. 2019. "Supervisor and mentoring effects on work-family conflict in logistics." *International Journal of Physical Distribution & Logistics Management* 49 (6):644-661.
- Michel, R. 2016. "2016 Warehouse/DC Operations Survey: Ready to Confront Complexity." *Supply Chain Management Review* November:52-59.
- Min, H. 2007. "Examining sources of warehouse employee turnover." *International Journal of Physical Distribution & Logistics Management* 37 (5):375-388.
- Mitchell, J.I., Gagné, M., Beaudry, A., and Dyer, L. 2012. "The role of perceived organizational support, distributive justice and motivation in reactions to new information technology." *Computers in Human Behavior* 28 (2):729-738.
- Morgeson, F.P., and Humphrey, S.E. 2006. "The Work Design Questionnaire (WDQ): developing and validating a comprehensive measure for assessing job design and the nature of work." *Journal of Applied Psychology* 91 (6):1321-39.
- Morris, M.G., and Venkatesh, V. 2010. "Job Characteristics and Job Satisfaction: Understanding the Role of Enterprise Resource Planning System Implementation." *MIS Quarterly* 34 (1):143-161.
- Romero, D., Stahre, J., Wuest, T., Noran, O., Bernus, P., Fast-Berglund, Å., and Gorecky, D. 2016. "Towards an Operator 4.0 Typology: A Human-Centric Perspective on the Fourth Industrial Revolution Technologies." Proceedings of the International Conference on Computers and Industrial Engineering (CIE46), Tianjin, China, 29–31 October 2016.
- Tompkins, J.A., White, J.A., Bozer, Y.A., and Tanchoco, J.M.A. 2010. *Facilities Planning*. 4 ed. Hoboken: John Wiley & Sons.
- Venkatesh, V., Bala, H., and Sykes, T.A. 2010. "Impacts of Information and Communication Technology Implementations on Employees' Jobs in Service Organizations in India: A Multi-Method Longitudinal Field Study." *Production and Operations Management* 19 (5):591-613.
- Waschull, S., Bokhorst, J.A.C., Molleman, E., and Wortmann, J.C. 2020. "Work design in future industrial production: Transforming towards cyber-physical systems." *Computers & Industrial Engineering* 139: 105679
- Winkelhaus, S., and Grosse, E.H. 2019. "Job Satisfaction in Digitalized Manual Workplaces: Insights from a qualitative assessment in intralogistics (working paper)."
- Winkelhaus, S., and Grosse, E.H. 2020. "Logistics 4.0: a systematic review towards a new logistics system." *International Journal of Production Research* 58 (1):18-43.