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Efficiency analysis for digitalised working systems of truck drivers

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Efficiency Analysis for Digitalised Working Systems of Truck Drivers

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The current research discussion postulates a digital transformation, characterized by new and in its extent unknown development and application potentials. At this stage scientists and practitioners know little about how these changes will transform specific work tasks. And the question is still even more opaque, whether there are real efficiency gains to be won by digitalization steps. Therefore, this paper develops an efficiency analysis to evaluate the effect of changing levels of digitalization within the working systems of professional truck drivers. Data Envelopment Analysis (DEA) is used in order to quantify truck driver performance in the logistics processes of a German food retailer. As inputs we use loading time and cost. Outputs are load factor of units, invoice charged to shops and value of damage. The findings indicate that a change in the level of digitalization entails a loss of efficiency in the first instance which can partly be compensated later. By using correlation analysis we prove a low statistical linear relationship of age and efficiency plus a strong statistical linear correlation of employer size and efficiency as well as period of employment and efficiency, always regarding the changing levels of digitalization in the working system of professional truck drivers. We derived the importance of employee retention programs for HR management along with a positive working environment provided for truck drivers to reduce fluctuation effects. Furthermore, we advise to design software for truck drivers as commonplace as possible and in the style of widespread smart phone software user interfaces.

Keywords: Digitalisation; Data Envelopment Analysis; Efficiency analysis; Truck driver

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1 Introduction

According to the results of a cross-sectoral survey of more than 500 German companies by the digital association Bitkom, 84% of companies with logistics processes rely on digital technologies (Bitkom, 2017, online). Referring to this digital transformation, the current research discussion postulates almost unanimously a development boost that is characterized by a new and in its extent unknown development with non-foreseeable application potentials (Avent, 2014, p. 2). The trend is referred by different views as "Second Machine Age" (Brynjolfsson and McAfee, 2014, p. 7), "Third Industrial Revolution" (Rifkin, 2011, p. 2; Markillie, 2012, p. 1), "Distributed Capitalism" (Zuboff, 2010, p. 1) or "Industry 4.0" (Kagermann, et al., 2011, p. 1). The social and economic consequences can be described as disruptive and affect logistics as a science discipline, activity and industry (Avent, 2014, p. 2; Koch, et al., 2014, p. 4; Wee, et al., 2015, p. 7). Yet scientists and practitioners know little about what exactly is behind these buzz words and how the emerging changes of working systems will transform work tasks or working relationships - and especially the question of efficiency improvements is without widespread empirical answers yet.

Therefore, this paper aims to develop and apply an efficiency analysis to evaluate the effect of changing levels of digitalization within the working systems of professional truck drivers. We aspire to answer the following research questions: What are the components of an efficiency analysis aimed to evaluate the effect of changing levels of digitalization within the working systems of professional truck drivers? (RQ1) Which level of efficiency exists before the change in the level of digitalization, how does it develop during and after the changeover? (RQ2) What effect has age, size of the employer and period of employment - hence work experience - on the level of efficiency? (RQ3).

After this introduction (section 1) we present a short literature review on impacts of digitalization on the human workforce in logistics and identify existing research gaps (section 2). In section 3, the efficiency analysis for digitalised working systems of truck drivers is elaborated by explaining basics of Data Envelopment Analysis, selecting applicable inputs and outputs for the efficiency analysis and explaining the setup and data collection. Based on the findings of the case study which are presented in section 4, section 5 of the paper discusses these results and derives implications for logistics management. The paper concludes with a summary and outlook in section 6.

2 Digitalization and human workforce in logistics

The logistics sector plays a key role in implementing Industry 4.0 solutions (BVL, 2017, p. 5), which raises the questions of consequences for employees and employers. From a sociological point of view, the human workforce can be theoretically structured in job clusters with mainly skilled and unskilled work tasks. The first group can be described as jobs that do not require profound vocational training, work that is carried out after short training on the job or a brief induction phase. On the other hand, qualified skilled workers play an important role: Typical occupational profiles include e.g. specialists in warehouse logistics, dispatchers, skilled workers in harbors and professional truck drivers (Eisenmann and Ittermann, 2017, p. 4). When investigating the human workforce, recent scientific literature also differentiates between blue-collar and white-collar workers.

The first describes a class of workers with primary physical working activities and is inspired by the blue working clothes that employees in the production sector use to wear. Their counterparts are white-collar workers who perform in professional, managerial, or administrative work whereby the expression is derived from the idea of a typical manager wearing white shirts. In this paper we examine qualified skilled workers in the working class of blue-collar workers.

2.1 Findings of literature review and resulting research gap

To identify an existing research gap, the development boost mentioned in section 1 was analyzed by a systematic bibliometric analysis based on Elsevier's abstract and citation database Scopus. Therefore, we concentrated on publications dealing with the impact of digitalization between 2008 and 2018 within the document types of textbooks, conference papers and journal articles. Furthermore, publications related to the sections of social sciences or business/management/accounting were investigated. We used TITLE-ABS-KEY ("impact" AND "digitalization") AND PUBYEAR > 2008 AND (LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "BUSI")) as search term. To illustrate the 154 resulting publications we applied VOSviewer, a software tool for constructing and visualizing bibliometric networks (van Eck and Waltman, 2010, p. 523). The bigger a circle, the more frequently the keyword appears in the publication set from Scopus. The keywords are assigned to a cluster, based on a computer algorithm. Each cluster has its own color related to the year of publication.

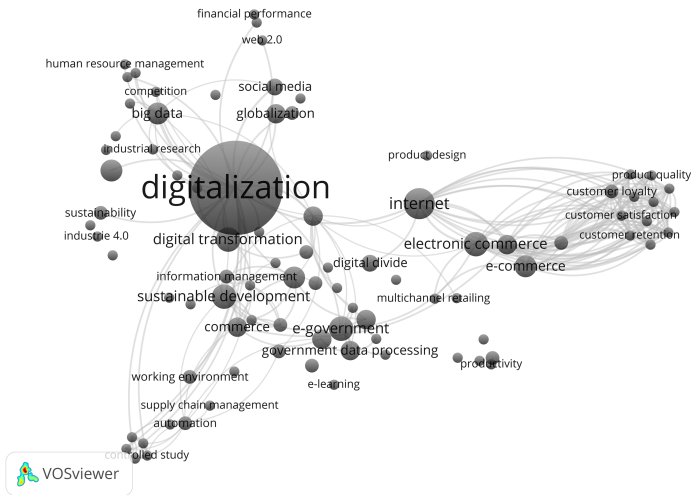


Figure 1: Keywords map of investigated publications

The results show that the current research discussion concentrates on the investigation of digitalization in the industrial sector (keyword e.g. industry 4.0, manufacture) and moreover on the impact on human workforce and existing working systems (keyword e.g. human, working environment, education). Therefore, the blue-collar workers in the logistics sector are hardly addressed. The research approaches of the publications are either conceptual frameworks (Dombrowski, et al., 2014; Hirsch-Kreinsen, 2015; Huchler, 2016; Eisenmann and Ittermann, 2017; Klumpp, 2018; Hirsch-Kreinsen, et al., 2018) or empirical studies based on qualitative research methods (Stowasser and Jeske, 2015; Windelband and Dworschak, 2015; Bauer and Schlund, 2015; Ahrens, 2016; Will-Zocholl, 2016; Wróbel-Lachowska, et al., 2018). Consequently, we identified a research gap for investigating the impacts of digitalization in logistics based on a quantitative methodology.

2.2 Impacts of digitalization on human workforce

Scientific contributions investigating the changes in organizations are often related to change management. It addresses the preparation, realization and analysis for developments or far-reaching changes aiming to improve the current situation of a company and the efficiency of company's activities (Vahs and Weiland, 2010, p. 7). There are several theoretical-conceptual approaches to describe organizational changes on a macro-level, e.g. Kotter's 8-Step Process for Leading Change (1995) or micro-level, e.g. Lewin's 3-Step Model (1947, 1963). Lewin was one of the first researchers who investigated the procedure and effects of changes, especially the reactions of groups that have to face planned changes. According to him, the process of change can be divided in 3 phases called "unfreezing", "moving" and "refreezing". Furthermore, the model states individual levels of efficiency depending on the current change phase (Lewin, 1947, p. 34). The following figure illustrates this development.

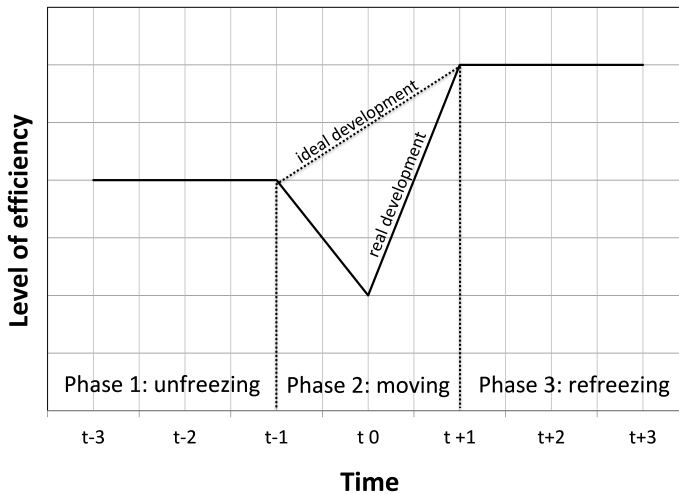


Figure 2: Theory of level of efficiency in change processes, following Lewin, 1963, p. 2017 in Mohr, 1997, p. 73.

In order to explain where the change takes place exactly, the model of a working system created by Hardenacke et al. is used (Hardenacke, et al., 1985). The focus of the model is the work task which is derived by a superior mission of the organization. To accomplish the working task, the human resource impinges on the work object by using work equipment (Luczak, 1997, p. 13). An interaction between humans and the work equipment is necessary and requires a certain level of qualification for successful interaction. Besides the inputs into the working system (e.g. energy, material and information) and the output factors (e.g. work results), there are exogenous factors influencing the working system and subsystems like the physical and social environment (Schultetus, 2006, p. 15). The truck drivers examined in this paper have to face changes in digital innovations related to track and trace systems. The work equipment is a mobile device used to display work tasks for the truck driver e.g. to load a certain amount of containers for a grocery store and deliver it within a given time window. In order to fulfill the task, the truck driver has to scan all relevant 1D barcodes which are attached to the containers, load them into his truck and record differences between the data provided by the mobile device and the determined condition of transported goods.

3 Efficiency analysis for digitalised working systems of truck drivers

There is a wide variety of definitions for the term efficiency in scientific literature. Forsund and Hjalmarsson already described in 1974: "Efficiency is a word easy to use, but very difficult to give a precise operational meaning (Forsund and Hjalmarsson, 1974, p. 152)." Current research approaches postulate almost unanimously that there is no uniformly widespread definition for the concept of efficiency in business literature (Tzika, et al., 2017, p. 530). Efficiency in this research is understood as the relationship between the results achieved (outputs) and the resources used (inputs) for this purpose (DIN EN ISO 9000, 2000, p. 22). To measure efficiency quantitatively, performance measurement differs between key figures, parametric (e.g. Ordinary Least Squares, Stochastic Frontier Analysis) and non-parametric efficiency analysis (e.g. (Stochastic) Data Envelopment Analysis). The main difference is that non-parametric methods do not require a functional relationship between input and output factors whereas parametric methods do (Burger, 2008, p. 48).

3.1 Data Envelopment Analysis

The data envelopment analysis (DEA) method is a non-parametric optimization method of mathematical programming for measuring the relative efficiency of decision making units (DMUs) that have multiple inputs and outputs. A basic model was introduced by Charnes et al. (Charnes, et al., 1978, pp. 429–444) and is based on Pareto’s definition of economic efficiency (Pareto, 1897), Koopmans activity analysis concept (Koopmans, 1951) together with the publications of Debreu and Farrell dealing with radial efficiency measurement (Farrell, 1957; Debreu, 1951). The increasing use in scientific research is related to the extensive scope of application where DMUs can be organizations or organizational units such as banks (Chen, et al., 2018; Huang, et al., 2018), universities (Lee and Worthington, 2016; Yang, et al., 2018), airlines (Omrani and Soltanzadeh, 2016; Chen, et al., 2017), employees (Khodamoradi, et al., 2016; Dugelova and Strenitzerova, 2015; Azadeh and Mousavi, 2014; Du, 2013; Zbranek, 2013; Shirouyehzad, et al., 2012) or nations (Malhotra and Malhotra, 2009). Further advantages beyond multiple inputs and outputs included are the facts that DEA is solely based on empirical data without the need of a priori existing production function and the fact that there is no need to weight factors, as this is done endogenously by the mathematics optimization model. The production process or throughput is seen as a black box. The basic mathematical notation is as follows (Wilken, 2007, p. 35):

$$\text{eff DMU}_0 = \frac{\text{virtual outputs of DMU}_0}{\text{virtual inputs of DMU}_0} = \frac{\sum_{j=1}^s u_{0,j} y_{0,j}}{\sum_{i=1}^m v_{0,i} x_{0,i}} \quad (1)$$

eff	Abbreviation for efficiency
DMU ₀	DMU with index 0 as exemplary decision unit
s:	Number of outputs to each DMU
m:	Number of inputs to each DMU
$u_{0,j}$:	The weight assigned to the output
$v_{0,i}$:	The weight assigned to the input
$y_{0,j}$:	Amount of the j output produced by DMU 0
$x_{0,i}$:	Amount of the i input consumed by DMU 0

The basic idea is to calculate an efficiency frontier that is used as a best practice input-output-combination for the underlying production scenario. DMUs that are on the efficiency frontier are considered as 100% efficient, whereas the relative inefficiency of a DMU can be determined by measuring the distance between individual DMU performance and the efficiency frontier. As the equation above requires n calculations for all n DMUs, the optimization problem is solved by a linear programming formulation (Charnes, et al., 1978, pp. 435–437). The optimization method can furthermore be based on constant returns on scale (CRS) in the CCR-model (Charnes, et al., 1978) or variable returns on scale (VRS) in the BCC-model (Banker, et al., 1984) and in each case with an input or output orientation.

3.2 Selection of applicable inputs and outputs for DEA

In this paper we analyze the efficiency of truck drivers working in the sector of distribution logistics for a large German food retailing company. Their transportation unit is responsible for delivering food and non-food items from the central logistics center to all grocery shops of the relevant delivery area complete and on time as well as for returning recyclable materials plus empty load carriers from the grocery shops back to the logistics center. To get a clear idea of the underlying scenario, the description is divided in financial flows and physical material flows related to the retailers supply chain.

From a financial point of view, the sales unit of the retailing company is charged by the logistics unit with individual service costs based on cost rates determined at the beginning of a financial year. It can be seen as a revenue stream for the logistics unit. To deliver all orders, the food retailing company uses solely carriers of different sizes whereby the tours are planned by the dispatchers of the retailing company. The carriers receive a payment for the physical distribution which is based on transported units. On the other hand the carriers have to pay for goods damaged in the delivery process.

Focusing the daily business of professional truck drivers and the physical material flows, the work process can be divided in the following steps: (1) Register at the responsible dispatcher in the logistics center, (2) Receive data for delivery tour through mobile device, (3) Load the truck by scanning barcodes on load carriers through mobile device, (4) Receive freight documents from dispatcher, (5) Drive to n grocery shops, (6) Unload cargo at n grocery shops, (7) Return recyclable

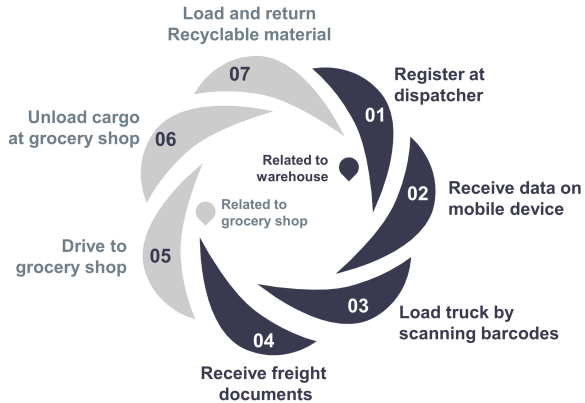


Figure 3: Illustration of work tasks of professional truck driver

material and empty load carriers back to logistics center. Hence, the question arises where truck drivers get in touch with a change in the level of digitalization and where they feel a change in their daily business. The following Figure 3 illustrates the work tasks of a professional truck driver in the given scenario.

Therefore, we choose to investigate the loading process (2) and (3). Analyzing the whole chain is unsuitable due to the fact that too many confounding factors e.g. waiting time at logistics center or grocery shops, traffic jams and vehicle breakdowns can distort the factor time as an important element in an efficiency analysis. The sub-processes (1), (4) and (5) are unsuitable because a change in the level of digitalization does not affect them. Furthermore, (6) and (7) are suitable for the scenario but require less interaction with the mobile device than (2) and (3).

For the DEA we use the loading time needed to load the truck and occurring transportation costs as inputs. The second factor is quantified by the payment to

carriers for transported units. Choosing the whole payment is unsuitable as this does not take into account that only a sub-process, the process of loading the truck, is analyzed. Therefore, we use a percentage of the whole payment based on the ratio of needed loading time and total time of a tour, whereby latter is the planned total time of a tour based on the calculation of the route planning software to avoid confounding factors like traffic jams or waiting time.

$$\text{Relevant transportation costs} = \frac{\text{Actual loading time}}{\text{Planned total time of tour}} \times \text{Total payment} \quad (2)$$

As outputs we use 3 factors. The first one is the invoice of the transportation unit of the retailing company to the sales unit for all rendered logistics services where we do not use the whole amount but the equal percentage as for the input transportation costs. It can be seen as a revenue for the logistics sector which is often used as an output factor for performance evaluation of logistics firms based on a DEA model (Hong and Xu, 2015; Momeni, et al., 2015; Tang, et al., 2015; Ye, 2015). The second output factor is the monetary value of all goods that are damaged or destroyed while loading the truck. In this case we do not use the sales prices of goods that can be found in the grocery shops but the purchase price of the food retailing company which presents the product value at the time of damage. As high output values increase the efficiency of DMUs we use the reciprocal calculated by the following formula.

$$\text{Damage value of DMU} = \frac{\text{Max. observed damage}}{\text{damage caused by DMU}} \quad (3)$$

The third output factor is related to the transport units that are loaded into the truck. We could simply use the amount of units and argue that when loading a roller container (square measure 72cm x 81,5cm and max. load 500kg) or a bigger pallet (square measure: 120cm x 80cm and max. load 1500kg) one barcode scan is required and therefore, the effort is equal. But with regard to the driver loading his truck, the different weights of the transport units cause a fundamental difference in the effort of handling. We take this unequal effort into account by rating loading equipment based on their geometrical square measure. Therefore,

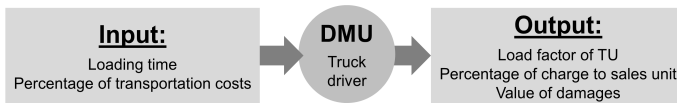


Figure 4: Components of the efficiency analysis

1.0 transport unit (TU) shall correspond to the dimensions of a roller container and all others are converted based on this standard, e.g. 1.64 TU for a pallet $[(120cm \times 80cm) / (72cm \times 81,5cm)]$. With the justification of every single input and output factors we can answer RQ1 "What are the components of an efficiency analysis aimed to evaluate the effect of changing levels of digitalization within the working systems of professional truck drivers? (RQ1)" and summarize the results of the elaboration in the following Figure 4.

3.3 Setup and data collection

To analyze the efficiency levels for digitalised working systems of professional truck drivers, the daily loading activities for 30 of them were examined during 4.5 weeks by evaluating 1,344 delivery tours. The digital change in the underlying scenario was the replacement of mobile devices based on windows mobile software with complex operation using a keyboard, by new mobile devices based on Android software with a user friendly full touch display. Another major modification was the integration of more and new processes into the existing workflow that is handled by the mobile device and have not been included before, e.g. special application for high value products like cigarettes, elimination and digitalization of accompanying documents along with a clear menu navigation.

To be able to prove that the developments in efficiency levels are not based on external factors, the results of a $n = 15$ group with $n = 15$ of professional truck drivers with digitalization (DG) are contrasted with a $n = 15$ control group (CG, $n = 15$) of professional truck drivers without any changes in the level of digitalization. The change was done at the beginning of calendar week 16 (t_0). To get an own empirical curve progression based on Lewin's 3-Step Model we analyzed the 3 phases "unfreezing" ($t - 4, t - 3, t - 2, t - 1$), "moving" (t_0) and "refreezing" ($t + 1, t + 2, t + 3, t + 4$). The sociodemographic structure of the digitalized group and the control group has been chosen identically in order to

guarantee a maximum level of construct validity. The following figure shows the sociodemographic structure.

Furthermore, we analyzed the period of employment of relevant professional truck drivers. As the retailing company only uses carriers, information about the period of employment of truck drivers is not relevant, when investigating the impact of digitalization. Therefore, we enquired the truck drivers about their time of occupation at the transport unit of the food retailing company. Figure 5 shows the results for the digitalization group and the control group.

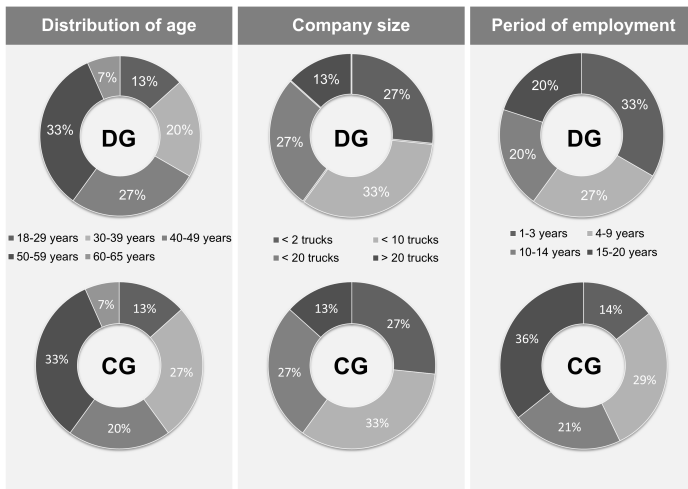


Figure 5: Sociodemographic structure of digitalized and control group

4 Findings of the case study

In the case study we use an input oriented model as the company aims to minimize loading time of professional truck drivers and cost for transportation. The

Table 1: Statistical measures for results of CCR-model

Period	Digitalized group D			Control Group C			Diff. of mean values
	Min	Mean	Max	Min	Mean	Max	
$t - 4$	0.80	0.93	1.00	0.64	0.94	1.00	+0.01
$t - 3$	0.78	0.93	1.00	0.68	0.94	1.00	+0.01
$t - 2$	0.79	0.94	1.00	0.86	0.94	1.00	± 0.00
$t - 1$	0.72	0.92	1.00	0.85	0.93	1.00	+0.01
$t 0$	0.63	0.80	1.00	0.61	0.86	1.00	+0.06
$t + 1$	0.74	0.89	1.00	0.76	0.91	1.00	+0.02
$t + 2$	0.77	0.93	1.00	0.76	0.92	1.00	-0.01
$t + 3$	0.67	0.89	1.00	0.66	0.91	1.00	+0.02
$t + 4$	0.78	0.92	1.00	0.69	0.88	1.00	-0.04

investigation was done during 4.5 weeks what we divided into 9 periods with 3 days (MO-WE and TH-SA) each. We chose $t - 4, t - 3, t - 2, t - 1$ as periods before the change, $t 0$ as the time frame of the change and $t + 1, t + 2, t + 3, t + 4$ as periods after the change. All truck drivers of the digitalized group received their new mobile devices at the beginning of $t 0$ and before starting their daily work. The following table shows relevant statistical measures for the results of the DEA CCR model calculation.

We chose a CCR-model with constant returns on scale which is most commonly used as a basic model in scientific literature. This can be explained by the underlying assumption regarding the optimal operational size (Cantner, et al., 2007, p. 11). A DMU under evaluation that operates with CRS performs with a most productive scale size (MPSS). Therefore CRS assume that all DMUs exhibit an optimal operational size. The concept of MPSS has been defined by Banker, et al. where DMUs do not naturally operate at MPSS but would achieve it by scaling its operations up and down via VRS (Banker, 1984, p. 39). Hence BCC-model is only applied when it is specifically required to check for increasing or decreasing returns to scale. As we assume that the MPSS, in the case of professional truck drivers performance defined as the individual performance capability, is equal for each DMU the CCR-model is applied. The following Figure 6 illustrates the curve progression of DEA efficiency measures for $t - 4$ to $t + 4$.

The graphs in Figure 6 show that the efficiency of the digitalized group decreases significantly in $t 0$ where the change in digital technology took place. The data

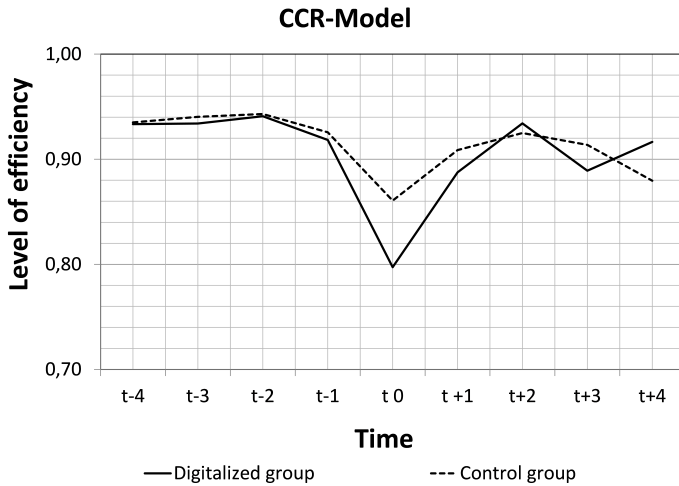


Figure 6: Curve progression of DEA efficiency measures for $t - 4$ to $t + 4$

cannot be interpreted solely by the total efficiency values, but by the difference between the mean values of the 2 groups. Before the digitalization process the curves were closely related with a deviation of max. 1% but in t_0 the differences in efficiency values are 6% in the BCC-model. This is enough evidence to answer RQ2 "Which level of efficiency exists before the change in the level of digitization, how does it develop during and after the changeover?": Before the change there is an efficiency level of an average of 93% (CCR-model) and during the change in the level of digitalization we monitored a significant loss of efficiency that increased to the former level in $t + 2$. After the changing level of digitalization the level of efficiency averages 91% and is therefore higher than during the change but lower than before. We assume that the effect of an increasing level of efficiency through digitalization will occur in long-term investigations which outline further research needs.

To be able to answer RQ3 "What effect has age, size of the employer and period of employment on the level of efficiency?" we use a correlation analysis to investigate

the statistical relationship between the level of efficiency and sociodemographic attributes. We chose the efficiency values of t_0 (CCR-model) for the group with digitalization as it is the period where the change in the level of digitalization takes place. A high efficiency in this period proves that the driver is affected by the change but still efficient in the work he does.

The correlations coefficient r for the relationship of "age in years" (x) and "level efficiency" (y) is $r = 0.1496$. Therefore, there is a low statistical linear relationship between these 2 factors. The following figure shows the correlation graphs for the relationship of "total trucks of company" for the carrier's size (x) and "level of efficiency" (y) as well as the relationship of "period of employment" at the food retailing company and not as a truck driver (x) and "level of efficiency" (y).

Due to the correlation coefficients there is a strong positive linear statistical relationship between a company's size and the level of efficiency during a digital change. Furthermore, we can determine a strong positive linear statistical relationship between the period of employment in a certain occupation and the level of efficiency during a digital change. These findings answer RQ3.

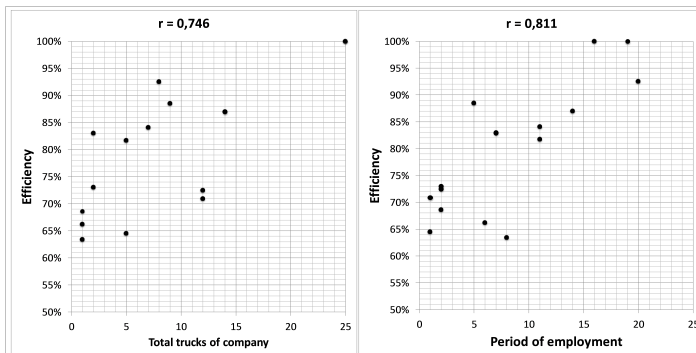


Figure 7: Correlation graphs for company size and period of employment

5 Discussion and implications for management

The curve progression of the analysis indicates a loss of efficiency during the first days of the change which has been explained in the previous chapter. In addition, the investigation shows that the initial level is not constantly reached in the periods after. Due to the limited periods included into the analysis we cannot answer the question if the increasing level of digitalization can increase the level of efficiency for this case.

The results of the correlation analysis indicate that age is less relevant when discussing the changing levels of digitalization for professional truck drivers. One reason for this is that mobile devices like mobile phones became a part of our every day's life, independent of our age or social status. More than 10 years ago the use of internet and mobile devices was interpreted as a border that had to be crossed and where users had to intentionally go to. This can be understood by reenacting the motto of the internet conference re:publica in 2007 called "living in the internet". Digital devices and the internet are no parallel worlds to go into any more, it rather became a medium that permanently and unconsciously expands the reality we are living in. All of the professional truck drivers investigated in this case possess a private smart phone and are therefore used to the full touch display introduced with the mobile devices. A recommendation for IT business units and software engineers is to design virtual dialogues on mobile devices as commonplace as possible. For HR management our analysis gives indications that the age of employees will less be a problem in regards to changing levels of digitalization. The results of the correlation analysis investigating the size of the company can be traced back to the fact that bigger carriers use supervisors to coordinate truck drivers and their service at the logistics unit of the food retailing company. A direct contact for questions has a positive impact on the efficiency level when changing the levels of digitalization. This can be a hint for logistics process management to invest in experts helping all truck drivers by placing them on the area of outgoing goods in the logistics center to weaken the negative effects on efficiency levels. The last correlation analysis with the period of employment at the food retailing company indicated that being proficient in the company's processes can be essential for a successful analog-to-digital conversion. An employment of more than 5 years and the knowledge gained in this time seems to be a valuable asset. This means that HR management of carriers should concentrate on developing and promoting employee retention programs to lower fluctuation effects of professional truck drivers. For the contracting authority, in our case the

food retailing company, it also means to provide a positive working environment with short waiting times, clear objectives and permanent support.

6 Conclusion and outlook

The aim of this paper was to develop and apply an efficiency analysis to evaluate the effect of changing levels of digitalization within the working systems of professional truck drivers. RQ1 "What are the components of an efficiency analysis aimed to evaluate the effect of changing levels of digitalization within the working systems of professional truck drivers?" was answered by the development of a DEA analysis using loading time and percentage of transportation costs as input factors plus load factor of TU, percentage of charge to sales unit and value of damage (reciprocal) as output factors. We applied the analysis in order to evaluate the truck driver's (DMU) performance in the logistics sector of a food retailing company. On the basis of this case study we answered RQ2 "Which level of efficiency exists before the change in the level of digitization, how does it develop during and after the changeover?" by deriving the curve progression of relative efficiency during 4.5 divided in 9 periods with 3 days each. Before the change there was an efficiency level of an average of 95% (BCC-model) and during the change in the level of digitalization we monitored a significant loss of efficiency that increased to the former level in $t + 2$. Finally RQ3 "What effect has age, size of the employer and period of employment on the level of efficiency?" was answered by correlation analysis comparing the level of efficiency during the change in the level of digitalization (t_0) with the age of the truck drivers, the size of their employers and their period of employment at the German food retailer. We showed a low statistical linear relationship of age and efficiency plus a strong statistical linear relationship of employer size and efficiency as well as period of employment and efficiency, always regarding the changing levels of digitalization in the working system of professional truck drivers.

The contributions and implications presented in this article were taken from a quantitative (DEA analysis) and explanative (related to Lewin's 3-Stage Model of Change) approach, which is why the results have limitations and an enlargement of the scope would enable new insights in the future: We did not include further qualitative input and output factors like the satisfaction or motivation of truck drivers. Moreover, we examined a change in the level of digitalization without any training methods applied to prepare the professional truck drivers.

Therefore, research is necessary and interesting along the lines of the following possible research questions: (i) How can qualitative soft factors like employee's satisfaction and motivation be integrated in an efficiency analysis for professional truck drivers? Current research approaches regarding human resource management include soft factors into DEA for efficiency measurement of employees (Shirouyehzad, et al., 2012; Zbranek, 2013; Du, 2013; Azadeh and Mousavi, 2014; Dugelova and Strenitzerova, 2015; Khodamoradi, et al., 2016). Furthermore, (ii) How and to which extend can training methods like seminar based training or self-studies with digital mock ups reduce negative effects in the level of efficiency when changing the level of digitalization for professional truck drivers? These questions would constitute interesting research pathways following the first quantitative results presented here.

Altogether, the presented analysis and management implications have shown the importance and value of a quantitative-empirical approach regarding the digital transition in specified logistics processes and human work contexts. This will be a long-term research and business practice question for the future of logistics.

References

- Ahrens, D. (2016). "Neue Anforderungen im Zuge der Automatisierung von Produktionsprozessen: Expertenwissen und operative Zuverlässigkeit". In: *Arbeits- und Industriepsychologische Studien* 9.1, pp. 43–56.
- Avent, R. (2014). "The third great wave". In: *The Economist Special Report*, pp. 1–14.
- Azadeh, A. and A. Mousavi (2014). "The Impact of Job Security, Satisfaction and Stress on Performance Assessment and Optimization of Generation Companies". In: *Journal of Loss Prevention in the Process Industries* 32, pp. 343–348.
- Banker, R. D. (1984). "Estimating most productive scale size using data envelopment analysis". In: *European Journal of Operational Research* 17.1, pp. 35–44.
- Banker, R. D., A. Charnes, and W. W. Cooper (1984). "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis". In: *Management Science* 30.9, pp. 1078–1092.
- Bauer, W. and S. Schlund (2015). "Wandel der Arbeit in indirekten Bereichen: Planung und Engineering". In: *Digitalisierung industrieller Arbeit*. Ed. by H. Hirsch-Kreinsen, P. Itermann, and J. Niehaus. Baden-Baden: Nomos Verlagsgesellschaft, pp. 54–69.
- Bitkom (2017). *Digitalisierung der Logistik*.
- Brynjolfsson, E. and A. McAfee (2014). *The second machine age: Work, progress, and prosperity in a time of brilliant technologies*. New York: W.W. Norton & Company.
- Burger, A. (2008). "Produktivität und Effizienz in Banken: Terminologie, Methoden und Status quo". In: *Frankfurt School – Working Paper Series* No. 92.

- BVL (2017). "Logistik als Wissenschaft: Zentrale Forschungsfragen in Zeiten der vierten industriellen Revolution". In: *Positionspapier Bundesvereinigung Logistik (BVL) e. V.*
- Cantner, U., H. Hanusch, and J. Krüger (2007). *Produktivitäts- und Effizienzanalyse: Der nicht-parametrische Ansatz*. Berlin: Springer.
- Charnes, A., W. W. Cooper, and E. Rhodes (1978). "Measuring the efficiency of decision making units". In: *European Journal of Operational Research* 2.6, pp. 429–444.
- Chen, Z., R. Matousek, and P. Wanke (2018). "Chinese bank efficiency during the global financial crisis: A combined approach using satisficing DEA and Support Vector Machines?". In: *The North American Journal of Economics and Finance* 43, pp. 71–86.
- Chen, Z., P. Wanke, J. J. M. Antunes, and N. Zhang (2017). "Chinese airline efficiency under CO2 emissions and flight delays: A stochastic network DEA model". In: *Energy Economics* 68, pp. 89–108.
- Debreu, G. (1951). "The Coefficient of Resource Utilization". In: *Econometrica* 19.3, pp. 273–292.
- DIN EN ISO 9000 (2000). *Qualitätsmanagementsysteme: Grundlagen und Begriffe*. Berlin: Beuth.
- Dombrowski, U., C. Riechel, and M. Evers (2014). "Industrie 4.0: Die Rolle des Menschen in der vierten industriellen Revolution". In: *Industrie 4.0*. Ed. by W. Kersten. Schriftenreihe der Hochschulgruppe für Arbeits- und Betriebsorganisation e.V. (HAB). Berlin: Gito, pp. 129–153.
- Du, J.-Y. (2013). "Staff performance appraisal based on data envelopment analysis (DEA)". In: *Journal of Chemical and Pharmaceutical Research* 5.11, pp. 102–105.
- Dugelova, M. and M. Strenitzerova (2015). "The Using of Data Envelopment Analysis in Human Resource Controlling". In: *Procedia Economics and Finance* 26, pp. 468–475.
- Eisenmann, M. and P. Ittermann (2017). "Hybride Dienstleistungen und Wandel der Arbeit: Herausforderungen und Perspektiven in der Logistik". In: *Soziologisches Arbeitspapier* 50, pp. 1–46.
- Farrell, M. J. (1957). "The measurement of productive efficiency". In: *Journal of Royal Statistical Society* 120.3, pp. 253–290.
- Forsund, F. R. and L. Hjalmarsson (1974). "On the Measurement of Productive Efficiency". In: *The Swedish Journal of Economics* 76.2, pp. 141–154.
- Hardenacke, H., W. Peetz, and G. Wichardt (1985). *Arbeitswissenschaft*. Studienbücher der Wirtschaft. München: Hanser.
- Hirsch-Kreinsen, H. (2015). "Gestaltungsperspektiven von Produktionsarbeit bei Industrie 4.0". In: *Arbeit in der digitalisierten Welt*. Ed. by C. Schlick. Frankfurt am Main: Campus.
- Hirsch-Kreinsen, H., P. Ittermann, and J. Niehaus, eds. (2015). *Digitalisierung industrieller Arbeit: Die Vision Industrie 4.0 und ihre sozialen Herausforderungen*. 1. Auflage. Baden-Baden: Nomos Verlagsgesellschaft.
- Hirsch-Kreinsen, H., M. ten Hompel, P. Ittermann, J. Dregger, J. Niehaus, T. Kirks, and B. Mättig (2018). "'Social Manufacturing and Logistics': Arbeit in der digitalisierten Produktion". In: *Zukunft der Arbeit*. Ed. by S. Wischmann and E. Hartmann. Berlin: Springer Vieweg.
- Hong, H. and D. Xu (2015). "Performance evaluation of logistics firms based on DEA model". In: *International Journal of Services, Technology and Management* 21.4-6, pp. 199–213.
- Huang, T.-H., K.-C. Chen, and C.-I. Lin (2018). "An extension from network DEA to copula-based network SFA: Evidence from the U.S. commercial banks in 2009". In: *The Quarterly Review of Economics and Finance* 67, pp. 51–62.
- Huchler, N. (2016). "Die 'Rolle des Menschen' in der Industrie 4.0: Technikzentrierter vs. humanzentrierter Ansatz". In: *Arbeits- und Industriesoziologische Studien* 9.1, pp. 57–79.

- Kagermann, H., W.-D. Lukas, and W. Wahlster (2011). "Industrie 4.0: Mit dem Internet der Dinge auf dem Weg zur 4. industriellen Revolution". In: *VDI Nachrichten* 13.
- Kersten, W., ed. (2014). *Industrie 4.0: Wie intelligente Vernetzung und kognitive Systeme unsere Arbeit verändern*. Schriftenreihe der Hochschulgruppe für Arbeits- und Betriebsorganisation e.V. (HAB). Berlin: Gito.
- Khodamoradi, M., M.-H. Behzadi, and M. Rostamy-Malekhalifeh (2016). "Evaluating of staff's performance with job satisfaction and Organizational Commitment approach by DEA: Case study: Khuzestan Oxin Steel Company". In: *International Journal of Data Envelopment Analysis* 4.2, pp. 945–949.
- Klumpp, M. (2018). "Automation and artificial intelligence in business logistics systems: Human reactions and collaboration requirements". In: *International Journal of Logistics Research and Applications* 21.3, pp. 224–242.
- Koch, V., R. Geissbauer, S. Kuge, and S. Schrauf (2014). *Chancen und Herausforderungen der vierten industriellen Revolution*. Frankfurt und München: PwC und Strategy&.
- Koopmans, T. C., ed. (1951a). *Activity Analysis of Production and Allocation: Proceeding of a Conference*. London: Wiley.
- Koopmans, T. C. (1951b). "An analysis of production as an efficient combination of activities". In: *Activity Analysis of Production and Allocation*. Ed. by T. C. Koopmans. London: Wiley, pp. 33–97.
- Lee, B. L. and A. C. Worthington (2016). "A network DEA quantity and quality-orientated production model: An application to Australian university research services". In: *Omega* 60, pp. 26–33.
- Lewin, K. (1947). "Frontiers in Group Dynamics". In: *Human Relations* 1.1, pp. 5–41.
- Luczak, H. (1997). "Kerndefinition und Systematiken der Arbeitswissenschaft". In: *Handbuch Arbeitswissenschaft*. Ed. by H. Luczak, W. Volpert, and T. Müller. Stuttgart: Schäffer-Poeschel, pp. 11–19.
- Luczak, H., W. Volpert, and T. Müller, eds. (1997). *Handbuch Arbeitswissenschaft*. Stuttgart: Schäffer-Poeschel.
- Malhotra, R. and D. K. Malhotra (2009). "Evaluating the efficiency of European Union integration". In: *International Journal of Commerce and Management* 19.3, pp. 233–252.
- Markillie, P. (2012). "A third industrial revolution". In: *The Economist* Special Report, pp. 1–10.
- Mohr, N. (1997). *Kommunikation und organisatorischer Wandel*. Heidelberg: Gabler Verlag.
- Momeni, E., M. Azadi, and R. F. Saen (2015). "Measuring the efficiency of third party reverse logistics provider in supply chain by multi objective additive network DEA model". In: *International Journal of Shipping and Transport Logistics* 7.1, pp. 21–41.
- Omrani, H. and E. Soltanzadeh (2016). "Dynamic DEA models with network structure: An application for Iranian airlines". In: *Journal of Air Transport Management* 57, pp. 52–61.
- Pareto, V. (1897). *Cours d'économie politique*. Paris.
- Rifkin, J. (2011). *The third industrial revolution: How lateral power is transforming energy, the economy, and the world*. New York: Palgrave Macmillan.
- Schlick, C., ed. (2015). *Arbeit in der digitalisierten Welt: Beiträge der Fachtagung des BMBF 2015*. 1. Aufl. Frankfurt am Main: Campus.
- Schultetus, W. (2006). *Arbeitswissenschaft von der Theorie zur Praxis: Arbeitswissenschaftliche Erkenntnisse und ihr wirtschaftlicher Nutzen*. Köln: Wirtschaftsverl. Bachem.
- Shirouyehzad, H., F. Hosseinzadeh Lotfi, M. B. Aryanezhad, and R. Dabestani (2012). "A Data Envelopment Analysis Approach for Measuring Efficiency of Employees: A case study". In: *The South African Journal of Industrial Engineering* 23.1, pp. 191–201.

- Stowasser, S. and T. Jeske (2015). "Arbeitswelt der Zukunft". In: *Arbeit in der digitalisierten Welt*. Ed. by C. Schlick. Frankfurt am Main: Campus.
- Tang, L., X. Huang, Y. Peng, and Z. Xiao (2015). "Analysis and evaluation of relative efficiency of warehousing and distribution operations based on mixed DEA model". In: *Chemical Engineering Transactions* 46, pp. 583–588.
- Tzika, A., S. Zelewski, and M. Klumpp (2017). "Effizienzentwicklung von Hochschulen in Deutschland". In: *Hochschuleffizienz*. Ed. by S. Zelewski, M. Klumpp, and N. Akca. Berlin: Logos Berlin, pp. 517–600.
- Vahs, D. and A. Weiland (2010). *Workbook Change-Management: Methoden und Techniken*. Stuttgart: Schäffer-Poeschel.
- van Eck, N. J. and L. Waltman (2010). "Software survey: VOSviewer, a computer program for bibliometric mapping". In: *Scientometrics* 84.2, pp. 523–538.
- Wee, D., R. Kelly, J. Cattel, and M. Breunig (2015). *Industry 4.0: How to navigate digitization of the manufacturing sector*. München et al.: McKinsey & Company.
- Wilken, R. (2007). *Dynamisches Benchmarking: Ein Verfahren auf Basis der Data Envelopment Analysis*. Wiesbaden: Deutscher Universitäts-Verlag.
- Will-Zocholl, M. (2016). "Die Verlockung des Virtuellen: Reorganisation von Arbeit unter Bedingungen der Informatisierung, Digitalisierung und Virtualisierung". In: *Arbeits- und Industrie soziologische Studien* 9.1, pp. 25–42.
- Windelband, L. and B. Dworschak (2015). "Arbeit und Kompetenzen in der Industrie 4.0: Anwendungsszenarien Instandhaltung und Leichtbaurobotik". In: *Digitalisierung industrieller Arbeit*. Ed. by H. Hirsch-Kreinsen, P. Ittermann, and J. Niehaus. Baden-Baden: Nomos Verlagsgesellschaft, pp. 71–86.
- Wischmann, S. and E. Hartmann, eds. (2018). *Zukunft der Arbeit: Eine praxisnahe Betrachtung*. Berlin: Springer Vieweg.
- Wróbel-Lachowska, M., Z. Wisniewski, and A. Polak-Sopińska (2018). "The role of the lifelong learning in Logistics 4.0". In: *International Conference on Applied Human Factors and Ergonomics* 1, pp. 402–409.
- Yang, G.-l., H. Fukuyama, and Y.-y. Song (2018). "Measuring the inefficiency of Chinese research universities based on a two-stage network DEA model". In: *Journal of Informetrics* 12.1, pp. 10–30.
- Ye, Y. Y. (2015). "Performance evaluation of logistics enterprise based on DEA model". In: *Proceedings of the International Conference on Management, Information and Educational Engineering, MIEE 2014* 1.
- Zbranek, P. (2013). "Data envelopment analysis as a tool for evaluation of employees' performance". In: *Acta Oeconomica et Informatica* 16.1, pp. 12–21.
- Zelewski, S., M. Klumpp, and N. Akca, eds. (2017). *Hochschuleffizienz: Konzeptionelle Herausforderungen und Lösungsansätze aus Sicht der betriebswirtschaftlichen Forschung*. Berlin: Logos Berlin.
- Zuboff, S. (2010). *Creating value in the age of distributed capitalism*. McKinsey Quarterly.