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"Power to the workers": Empowering shop floor workers with worker-centric digital designs

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Empowering shop floor workers with worker-centric digital designs

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Abstract

Purpose – The purpose of this paper is to reveal how information and communication technology (ICT) can empower shop floor workers in collaborative manufacturing environments.
Design/methodology/approach – The authors gather data from a mobile maintenance department of a steel manufacturing company and apply the method of a scenario-based design. The authors use data from interviews, observations and company documents to create problem and activity scenarios. The authors also demonstrate the development of a worker-centric digital design in multiple demonstration and evaluation cycles.
Findings – The authors find that ICT can be used to ensure that empowerment is not only a concept, but can sustainably empower daily operations.
Research limitations/implications – The authors contribute to theory by showing how structural empowerment can be used as a guiding theoretical lens to design ICT for shop floor workers in collaborative manufacturing work environments. These implications are limited to findings from a single case study.
Practical implications – The results provide an overview of different empowerment dimensions, namely, the access to information, resources, support and opportunities, that can support employees in collaborative manufacturing environments.
Originality/value – This paper is first in suggesting a framework of how ICT designs can be used to empower shop floor workers in collaborative manufacturing environments.

Keywords Innovation, Information management

Paper type Research paper

1. Introduction

Changing demands in the global markets lead manufacturing companies to increasingly transform previously mass-produced items into individualized products (Koren, 2010), thereby making the flexibility of production practices a key success factor of the twenty-first century (Nahmias and Olsen, 2015). To guarantee this flexibility, shop floor workers' problem solving and decision-making capabilities become increasingly important (Secchi and Camuffo, 2016). In order to enable such capabilities, companies need to empower employees by providing adequate structural conditions (Hirzel *et al.*, 2017).

Following the call of Walker *et al.* (2015) to explore and apply adequate behavioral theories from other disciplines in operations management, we adopt the structural empowerment theory (Kanter, 1993) as a lens to provide guidance on such structural conditions. According to the theory, elements such as "access to resources" or "access to information" support employees in their self-determined activities. A number of studies have shown positive effects of employees' structural empowerment such as higher commitment to the organization (Smith *et al.*, 2010), higher job satisfaction (Wong and Laschinger, 2013) and higher work effectivity (Orgambídez-Ramos and Borrego-Alés, 2014). The theory of structural empowerment fits very well as we want to provide a rich account on the design alternatives. Other theories like the job

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characteristics theory (Hackman and Oldham, 1976) help to explain the positive effect of standardized process designs in general – but they do not provide further details. In addition, psychological empowerment related to, e.g. self-efficacy and self-determination, is different with varying organizational structures (Spreitzer, 1995) so that it is important to set the best-fitting structures.

Whereas most of the existing investigations focus on the effects of structural empowerment, the organizational conditions that facilitate employees' structural empowerment have not yet been studied comprehensively. Although existing studies have shown the importance of communication in terms of feedback (Samuelsson and Nilsson, 2002), relevant information (Lillrank *et al.*, 2001; Swartling and Olausson, 2011), and team support (Angell and Corbett, 2009), concrete concepts about how to achieve these desired results are missing (Hirzel *et al.*, 2017). There is no clarity as yet on which structural approaches lead to increasing empowerment and finally to the above highlighted benefits. At the same time, the ways information and communication technology (ICT) can support workers are growing (Ravesteyn and Batenburg, 2010). ICT in this context is referring to worker-centric solutions which support collaborative manufacturing practices. That is, ICT supports employees in the location independent execution of operations and puts them in the center of shop floor design (May *et al.*, 2001; Richter *et al.*, 2017).

Combining those arguments, we need a better understanding of how ICT can provide the best possible support to empower shop floor workers in collaborative manufacturing environments. To address this issue, our question is: How can ICT empower shop floor workers in collaborative manufacturing environments?

In answering this question, we adopt the structural empowerment theory as an adequate behavioral theory since ICT refers to providing organizational support in terms of software and hardware to employees. The aim is to allow employees executing their daily work activities more independently. Hence, ICT empowerment concerns employees on the shop floor, in the sense of providing structural elements to allow for self-determined work activities for which the theory is adequate in explaining this relationship.

We studied the case of a mobile maintenance team at a production plant to explore these possibilities. As we do not intend to suggest design principles for one specific class of ICT, e.g. social software, but rather want to understand how ICT can improve existing practices, we apply a design approach in which we suggest activity scenarios as a way to illustrate how ICT can empower workers. Adopting this approach, we collected interview and observational data on the needs of the manufacturing workers and developed a worker-centric solution that targets the relevant dimensions of the structural empowerment theory (Kanter, 1993): information, resources, support and opportunities. As the subsequent evaluation of the prototype shows, ICT allows employees to connect cross-functionally as this approach is seen to have a positive impact on innovation activities in that it provides access to these dimensions.

Our study contributes to the operations management literature (e.g. Jurburg *et al.*, 2016; Hirzel *et al.*, 2017; Méndez and Rodriguez, 2017) by using the theory of structural empowerment as a useful theoretical perspective to ensure that ICT sustainably empowers daily operations. We show how a worker-centric solution addressing the theory's dimensions could be designed and add to the body of research from different streams in operations management, how ICT can support establishing empowerment. Based on the findings of this study, we furthermore suggest a framework that can serve as a guide on how to develop ICT solutions that can be used to empower shop floor workers in collaborative manufacturing environments. As such, we also contribute to the theory of structural empowerment in operations management in that so far it has not been used to explain how employees can be empowered to foster improvement and innovation via ICT (Hirzel *et al.*, 2017).

Next, we give the theoretical background, introducing the concepts of flexibility in production practices and structural empowerment.

2. Theoretical background

We conducted an extensive literature review as a starting point for our empirical research. With regards to scientific publications, we followed a structured approach (Webster and Watson, 2002) by searching leading journals using the keyword filters that the online databases EBSCO and IEEE Xplore, the ACM Digital Library and Google Scholar offer. Our search covered but was not restricted to the terms "empowerment" OR "empowerment theory" OR "structural empowerment" AND "ICT" or "digitalization" OR "smart factory" OR "industry 4.0." Conference proceedings were also considered in order to complete the list of articles. Forward and reverse searches provided us with additional relevant articles for our study.

2.1 Toward more flexible production practices

Manufacturing companies are currently encountering growing numbers of product variants along with an ageing staff component due to demographic changes (Herrmann *et al.*, 2014). These challenges oblige companies to develop their employees' competencies and to support related manufacturing knowledge practices (Patriotta, 2003; Virkkunen and Ahonen, 2004). In today's complex manufacturing environments, it is no longer the case that the knowledge requirements become less as the level of automatization rises (MacCrory *et al.*, 2014). Rather, the topics of knowledge shift from purely practical knowledge without automatization, to knowledge of the technical aspects of the machines in fully automated systems (Frey and Osborne, 2013; David, 2015). This corresponds to the shift in the worker's responsibility from producing goods to keeping technical systems in a production environment within the prescribed operating condition (Oliva and Kallenberg, 2003). Typical functions of employees working in this area include inspection, maintenance and repair activities that are performed on-site. Such activities can be characterized as internal service operations with customers being internal production staff respective managers in charge of the machines (Brandon-Jones and Silvestro, 2010). Internal service operations are mainly focused on an efficient delivery in terms of time, quality and cost with less emphasis on designing an optimal customer experience, e.g. in terms of physical layout or clothing (Paraskevas, 2001). In the case of manufacturing services (e.g. maintenance), the service operations can be characterized as shared services with being customer oriented, based on the requirements of the customers and operating mobile close to the machines (Strikwerda, 2014).

These functions have the potential to significantly influence the performance of organizations (Aurich *et al.*, 2006). However, the tasks vary in their objectives as well as regarding required information and resources, depending on their purpose (Aurich *et al.*, 2010). Therefore, providing the workers with intelligent support and appropriate knowledge is crucial and, in fact, a key driver of productivity (Bitner *et al.*, 2010). The increasing complexity of manufacturing environments demands better support by appropriate ICT that should be available where and whenever they are needed (Daeuble *et al.*, 2015). However, to date, very little research has been done on information needs and knowledge practices in the manufacturing sector (Becker *et al.*, 2011). ICT is important for empowering employees in this regard as this supports them in actively using and sharing their knowledge to improve performance and to openly discuss improvement opportunities and possible difficulties (Holtskog, 2013). Thus, in order to address this research gap, we suggest utilizing the theoretical lens of structural empowerment.

2.2 Structural empowerment

Empowerment is either related to the individual in the sense of cognitive conditions or to the environmental conditions of individuals (Thomas and Velthouse, 1990). While the environmental conditions can refer to situational attributes in general, organizational attributes have been highlighted as being the most important ones. Improving the latter is

termed as structural empowerment (Kanter, 1993). Kanter (1993, p. 210) describes power in this regard as the "ability to mobilize resources to get things done." Individuals are structurally empowered if they have access to four dimensions (Kanter, 1993; Lord and Hutchison, 1993; Laschinger *et al.*, 2004):

(1) access to information: information and knowledge necessary to perform tasks;

(2) access to resources: assets in terms of money, material and working time;

(3) access to support: reflecting own work practices by receiving guidance and feedback from colleagues and supervisors; and

(4) access to opportunities: learning opportunities to allow for knowledge and skills growth.

We use these four structural empowerment dimensions in our study as the guiding theoretical framework.

Organizations enabling these conditions for their employees can expect positive effects like higher commitment to the organization (Smith *et al.*, 2010), higher job satisfaction (Wong and Laschinger, 2013) or higher work effectivity (Orgambídez-Ramos and Borrego-Alés, 2014). Research has shown that if structural empowerment is not implemented properly, it can have negative side effects, such as higher complexity, increased time-pressure (Jantunen *et al.*, 2012) and the pressure to invent while working (Lee and Walsh, 2016).

2.3 The role of structural empowerment in operations management

Empowering employees is an important aspect in various streams of operations management research like total quality management (TQM), total production maintenance (TPM), continuous improvement or lean management. Such empowerment covers psychological empowerment (e.g. self-efficacy; Spreitzer, 1995) as well as structural empowerment which is mainly in the focus of operations management, i.e. creating the optimal organizational conditions for supporting employees (Orgambídez-Ramos and Borrego-Alés, 2014). Within lean management, it is highlighted that employees need to be enabled with the necessary tools to provide a best possible support for executing processes (Liker and Morgan, 2006; Rother, 2010). Research shows that structural empowerment is specifically important to foster continuous improvement activities (Fernandez and Moldogaziev, 2013; Jurburg *et al.*, 2016). In a similar manner, TQM highlights that quality assurance is an essential part of shop floor employees' work which should be achieved by transferring authority to employees as well as educating and training them (Dahlgaard and Dahlgaard-Park, 2006). Within TPM, the emphasis is on empowering small maintenance teams by assigning responsibility and providing autonomy (Méndez and Rodriguez, 2017). A main element of such empowerment is the provision of schedules, which however, in most cases, is still done in a paper-based manner (Heinrich *et al.*, 2018).

In order to achieve structural empowerment as well as to benefit from structural empowerment and reduce the associated risks described in these research streams, it is crucial to understand which methods, tools or systems can be applied to increase structural empowerment (Hirzel *et al.*, 2017). Here, communication in terms of feedback (Samuelsson and Nilsson, 2002), relevant information (Lillrank *et al.*, 2001; Swartling and Olausson, 2011) and team support is seen as important (Angell and Corbett, 2009), but concrete concepts for achieving these antecedents are missing.

Summing up, structural empowerment is an essential part of operations management with roots in different concepts discussed in the operations management literature. The characteristics of structural empowerment being addressed by the above-mentioned

approaches are mainly related to the dimensions "access to resources" and "access to opportunities." However, while employee empowerment is highlighted as being important, it is rarely discussed how empowerment can be supported best so that it is easy for employees to behave empowered. This is however important to be addressed as negative effects can be observed when there is a lack of sufficient support by an organization to ensure empowerment (Cunningham and Hyman, 1999).

2.4 The impact of ICT on empowerment

As highlighted in the introduction, when we refer to ICT, we mean solutions that support the location independent execution of operations by employees on the shop floor, i.e. worker-centric solutions to support collaborative manufacturing practices. There are a number of examples that illustrate the positive and negative effects of ICT on empowerment:

- The role of ICT with regard to empowerment of employees in operations management was first highlighted within process reengineering (Hammer and Champy, 1993). Performance should be improved by redesigning processes in a way that allows ICT to enable new practices. While the emphasis is on improving customer value, the lever ICT as proposed within reengineering leads to possibilities for increasing job enrichment and more autonomy of employees.
- A typical type of ICT supporting processes are those who provide employees with information that increases their decision-making authority, commonly referred to as workflow management systems (Reijers, 2003). Such systems can however also lead to a higher degree of standards regarding process execution (Caverlee *et al.*, 2007) and thus can be expected to have negative impacts on the empowerment of employees.
- Another group of ICT that supports employee awareness and information support is referred to as knowledge management or collaboration systems. Here the employees are more loosely (and less process-based) supported with information (Alavi and Leidner, 2001; Virkkunen and Ahonen, 2004; Campatelli *et al.*, 2016). For this kind of solutions, recent studies also show that private devices like smartphones (and related applications like WhatsApp) play an increasingly important role in manufacturing practices (Steinhüser *et al.*, 2017).

Summing up, ICT is recognized as being an important lever for enabling employee empowerment (Legner *et al.*, 2017). Linking the above illustrated studies to the dimensions of structural empowerment, it becomes obvious that the systems being analyzed in this regard mainly target "access to information" and "access to support." In that sense, prior studies on the role of ICT in empowerment complements prior work discussed in Section 2.3 in addressing these types of access, but does not account for a holistic view on the role of ICT in structural empowerment. In addition, it is not clear how exactly ICT can be used to support structural empowerment of employees, i.e. studying the underlying mechanisms, which is addressed in this paper.

3. Methodology

To understand how organizations can provide shop floor workers with empowerment structures, we conducted a case study at a large worldwide operating producer of high-quality raw material. We carried out an in-depth analysis of this single case in order to gain insight into empowerment structures that could be observed in a particular team within the company (Flyvbjerg, 2006), and to be able to study these complex situations in their specific context (Gibbert *et al.*, 2008). Subjectivity plays an important role in the cognitive processing of our data. So, instead of claiming objectivity, we rely on intersubjectivity (Dubé and Paré, 2003) by involving a team of researchers in the data

collection and analysis. Whereas single case studies usually do not allow for statistical generalization, we accept "analytical generalization" (Gibbert *et al.*, 2008) from our results to theory, rather than relying on a population to justify findings.

3.1 Case context

Our study focused on the fault repair and maintenance team of a global producer of high-quality raw material which employs about 28.000 people, further referred to as "ICSE." We particularly studied a team of 200 employees that is responsible for servicing and repairing about 3,000 electrical and air-conditioning devices in a German factory with 19.500 employees and a floor space of 9.5 square kilometers. The case represents a typical shared service in a manufacturing environment with mobile maintenance teams for spatially distributed machines. For ICSE, the specialist workers' knowledge in production is a crucial factor for fulfilling the constantly increasing quality and efficiency requirements, which also result in increasing task complexity. The dwindling number of employees and shorter training periods translate into a need for ongoing professional support and development of remaining employees' knowledge and competencies. In order to fulfill their tasks, the workers are supposed to react autonomously in highly complex situations; therefore, flexibility and diligence are expected.

3.2 Data collection and analysis

The data collection at the case company took place in several rounds between March 2015 and October 2016. We used different collection techniques and data sources (Benbasat *et al.*, 1987) to achieve richness and flexibility in the research process (Dubé and Paré, 2003). During the data collection, a very broad approach was adopted in order to understand how people complete their daily work and interact with each other, as well as to find out what tools are provided to support them. A team of three researchers observed ten employees while they were working on the company site. We further conducted 13 semi-structured interviews with an average length of 55 minutes each. Additionally, we studied diverse internal documents such as handbooks, work lists and process descriptions.

During the interviews, we asked participants questions covering their position on the following:

- general issues (age, use of a smartphone);
- current work practices (incl. access to information, resources and support);
- ideas for structural and process improvements;
- perceived opportunities for personal growth; and
- requirements to be met by an ICT.

The interviews were transcribed and then encoded each by one of the research team members. To use information from the text documents, we employed a qualitative content analysis (Mayring, 2000). We adopted a coding approach in which we searched for patterns following the dimensions of structural empowerment as presented in previous research (Kanter, 1993; Lord and Hutchison, 1993; Laschinger *et al.*, 2004). The coding set contained four categories which were split between access to information, access to resources, access to support and access to opportunities. These four categories are also reflected in the structure of the results.

3.3 Scenario-based design

In order to develop a future system we use a scenario-based design approach (Rosson and Carroll, 2002). This approach positions the users and their needs in the center of the design

by using scenarios who serve as rich descriptions of the current situation (problem scenarios) and the future system (activity scenarios) at an early stage. In a scenario-based design, the focus is not on functional specifications, but on the way the potential users habitually perform specific tasks or activities. A scenario is framed in such a specific way that it can be evaluated, but, at the same time, remains broad enough for it to be easily adapted (Rosson and Carroll, 2009). Figure 1 provides an overview on the procedure.

To prove the concept of the ICT solution to be developed in an ongoing exchange with future users we demonstrated and evaluated the designed artifact in multiple loops (Peffers *et al.*, 2007). This worker-centered design approach allowed for continuous improvement throughout the different prototype stages: mock-up, demonstrator, validator and pilot (cf. blinded for review).

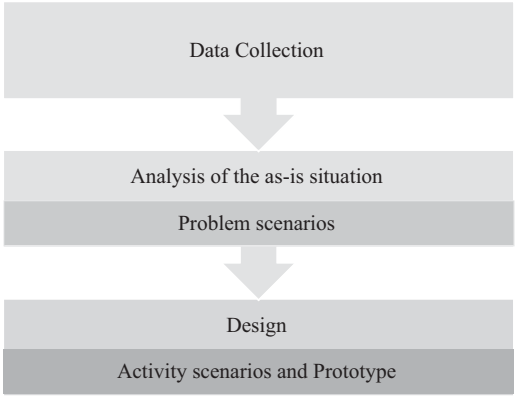
The first step in a scenario-based design process is the analysis of the current situation. To this end, the stakeholders are examined in detail in the course of field studies. The resulting information can be used to derive problem scenarios describing the current problems. Based on a problem scenario, a claims analysis can be carried out, which identifies the characteristics of a situation that has a significant effect on a persona. Such situational properties can be positive or negative, and thus show the trade-off of such a property (Rosson and Carroll, 2002). In the second phase of the scenario-based design process, activity, interaction and information scenarios are developed. Our focus is on activity scenarios which show how problems and opportunities of current practices are transformed into new behavioral patterns. The properties considered in the claims analysis serve as a basis for this. The third phase of the scenario-based design process comprises a summative and a normative evaluation of the scenarios. In the following, we will introduce the problem and activity scenario in the context of the case company.

4. As-is situation in the case company

4.1 A typical day of the maintenance team (Problem scenario)

Building on the insights that we gained from the data collection at ICSE, we created a problem scenario that describes the typical as-is situation of the workers and highlights current challenges that they are facing. This problem scenario serves as basis for the following analysis of the employees' current access to empowerment structures.

The maintenance team usually starts the day with the shift master dispatching the maintenance list and defect reports to the workers. Initially, faults are reported via



Source: Own figure based on Rosson and Carroll (2002)

Figure 1.
Research design

telephone, e-mail or fax. Subsequently, this crude information on the type of fault and system is handed to the mobile maintenance staff in the form of a paper document. However, the shift master often does not have enough time to prepare all work packages in detail. As a result, the installers sometimes lack crucial pieces of information about the unit of equipment that requires attention, e.g. whether a particular fault has occurred before, who the last person to maintain or repair the unit of equipment was, which tool and which protective equipment they require or whether problems at any plants should be prioritized. Hence, the workers spend a large amount of time discussing how to get the necessary information, resources and support instead of talking about priorities and the problem itself (Figure 2). Often, their work is doubled because on arrival, they are missing spare parts or there is some other unexpected situation at the plant. Frequently, they neither know the direct route to the problem's location, nor is a map available on the specific surroundings. Depending on where the faulty part is located, personal protective equipment might be necessary and/or special entry and exit procedures apply. Even though many employees have been working on the premises for a long time, they are not familiar with all the plants on the vast area. Usually, to find the right route and also the right person for security check-in and getting more detailed information, a number of colleagues have to be called. In case of an emergency, e.g. when a complete standstill occurs, this may be very costly time because of the large number of workers who are unable to continue working.

In a specific situation one of the tandem teams, Kim and Roland try to repair a broken air conditioner at the production site. Due to the broken air conditioner, the working temperature is about 60° C. Roland tries to get a grasp of what is wrong and what needs to be done, but because of the heat he has to take a break every 15 minutes. After 45 minutes, he discovers that the problem concerns the compressor. What he does not know is that the same problem has already presented itself a week before. Kim then tries to get Guenther, an electrician, on the phone so that a few minutes later, he knows where to pick up Guenther. While fetching him, Kim drives on to the tool shop to pick up the required spare part, which takes around 30 minutes. After losing almost two hours just getting started, they are back at the plant and start working. By then Roland is quite annoyed and says: "Things are so unnecessarily complicated. I have just called Ralf. He said he knows about the problem already, and if we had asked him in the morning he could have assisted us." In the end, they solve the problem, but with the uneasy feeling of having wasted two to three hours.

Figure 2.
Problem scenario: beginning of a shift – missing contextual information

When Kim and Roland's shift is almost over, there is one last issue on their list: an air conditioner at an important production site is not working properly. Kim opens the appliance and quickly sees what the problem is: "Roland, that is a case for an electrician," to which Roland answers: "Well, I will try to get one on the phone, but their shift is also almost over […]" A few minutes later, Roland talks to Bert, the electrician, who would like to help them, but is working on an emergency at the company headquarters and therefore cannot assist, even if it would have taken only a few minutes. So, Kim and Roland leave the site and go back to the tool shop without having achieved anything.

4.2 Current situation regarding the work empowerment structures

Based on the scenario illustrated above and relying on the theory of structural empowerment as described in Section 2.2, we analyzed the employees' current access to empowerment structures. We deduced that restricted access to information hampers the access to resources and support, which, in turn, limits adequate access to personal growth and learning opportunities. The results are summarized in the following.

4.2.1 Access to information. As described in the problem scenario, the multitude and variety of tasks make it virtually impossible for the employees to be familiar with every single plant. Often, necessary information, e.g. maps, construction plans, repair histories, are not immediately available. Interviewee 12 (further referred to as I_12) explained how restricted he perceives his access to information: "Certainly, much relevant information is stored somewhere in electronic form. However, we just don't know about it. It is very likely, that construction plans which may be important for us, reside somewhere on local computers. That makes it hard or even impossible for us to access them." Then, even having information on place and time, without direct access to other relevant information the employees are hindered in their decision making on how to proceed with a specific task in a concrete work situation.

4.2.2 Access to resources. As our data reveal, missing information often leads to a situation in which resources necessary for specific tasks are not immediately available, i.e. there is limited access to resources. I_10 described his hampered access to the possibility of taking a picture as follows: "I wanted to take a picture of a particular plant part and asked for the official way, how to do it: It is a very bureaucratic act. I would have to choose a camera, order it, pay 50 Euros for it, and in the end, I would have to wear another device around. I just don't feel like doing this work and carrying three devices. And it also takes too long." This quote demonstrates that the limited access to resources not only refers to tools, spare parts or protective equipment, but also to limited time resources in that often too much time is spent on sourcing missing materials.

4.2.3 Access to support. The employees at ICSE need to cooperate with and support each other, i.e. they need access to support. Often, specific problems arise that demand specialists' knowledge. However, as illustrated in the problem scenario, experts are hard to identify and not easy to reach in every situation, especially when no telephone is available or no network can be accessed. I_04 highlighted this by stating that "[…] it is quite difficult, to reach a particular person. We are ten people here in our team and have been provided with four cell phones. Hence, not everyone is reachable every time. [Only] when you pay attention in the morning to who is working with whom over the day, then you know, where to call."

4.2.4 Access to opportunities. Concerning access to opportunities, formally, the employees enjoy various development opportunities in the form of training programs or promotion prospects. Actually, the basic working conditions, such as constantly moving around and having too little time to spend on additional training, work against employees' personal growth. A lot of time is lost in coordinating rather than problem solving. One issue that was emphasized by the interviewees is the missing awareness of what the colleagues

are currently working on or have done recently. For example, I_08 stated that it may happen that "[…] when we arrive at a fault, we don't know that one of our colleagues was there two days ago. He already started to repair the machine but had to interrupt his work due to a missing spare part. If we knew that before, we could have contacted him and found a good solution together." This demonstrates how the missing awareness impedes the employees' opportunities for optimal problem solving and hence, for personal growth. Furthermore, a lot of knowledge actually gets lost with many experienced employees retiring. The "[…] knowledge about machines, the plant, the locations – this all goes down the drain" (I_01), hampering the younger workers to build their knowledge on the valuable knowledge and experiences of the older ones.

5. Intervention

Building on the practical problem situation described above, as well as the theoretical considerations about workplace empowerment, we created an activity scenario (further referred to as ICSE.me) that demonstrates the potential improvements an ICT solution could effect in supporting the employees in their daily work. This activity scenario serves as a unit in the following analysis.

5.1 Potential improvements (activity scenario)

The shift master uses ICSE.me to prepare the work packages. He adds relevant contextual information to the fault descriptions and sends them to his colleagues' smart devices (Figure 3). These briefings are messages that include information about required tools, protective equipment, locations, contact persons for security check-in, as well as the maintenance history. When logging into ICSE.me with one of the tool shop tablets, Kim sees his personal dashboard with all the relevant work packages; essentially, he finds a list of places where he and Roland will have to repair specific issues. When the shift master comes by to talk to Kim and Roland, they go through all the tasks, and reflect on how to solve the problems. By setting priorities, Kim and Roland can optimally prepare themselves for the work day.

Figure 3.
Activity scenario: beginning of a shift – an informed start

Kim and Roland have a look at one specific problem at the production site. The logbook functionality enables them to find information on the last maintenance and repair action that was carried out on the particular device. They see that Ralf has been there one week earlier and consult him on that issue. Ralf is certain that the problem lies with the compressor. With that piece of information in mind, Kim asks Roland who would be the best available electrician for that kind of job. Roland knows that Guenther can assist and then sends a text message through ICSE.me asking Guenther whether he would have time to help on that day. The logbook entries further give information which advises them to stop at the tool shop to get some of the special fuses that were the cause of the problem the previous three times. Detailed information on devices originates in the connected enterprise resource planning system. With such progressive planning in place Kim, Roland and Guenther go to the plant together and fix the issue very quickly by changing a few fuses of the compressor and making a few small adjustments. The work at the production site is still not easy with a working temperature of 60°, but thanks to the solution already worked out, they do not need much time to research: they can simply fix the problem. After completing the work on the crane, Roland enters a text message and attaches an optional video or pictures in the logbook. He notices that the problem always comes up with the same kind of compressor. He reminds himself to reflect further on this problem and look for possible solutions by immediately creating an entry in his personal idea management system via ICSE.me. This entry allows him to generate a text message to the shift manager suggesting a switch to another type of compressor.

Next, an air conditioner at an important production site is not working properly. An electrician is needed, but the first electrician Roland can think of, Guenther, is not on-site anymore. However, thanks to ICSE.me, the Yellow Pages are available on the mobile devices of maintenance crew, where Roland notices that one of Guenther's colleagues, Bert, who is also an expert in this field, is online. Roland talks to Bert, who tells him he would like to help them but he is working at the headquarters and cannot assist immediately. Bert does, however, have a few minutes because he is waiting for his trainee to bring some spare parts. So, Roland starts a video call, and shows Bert the problem that Kim discovered. Bert smiles and says: "That's an issue that we can solve remotely! Kim, please replace the fuse on the left-hand side, disconnect the yellow sensor, and restart. That should solve the problem for today. I think the sensor is defective, but it is only an add-on – the air conditioner will run without this sensor. Tomorrow I will get to the site and replace the entire plug connection, so that the problem is solved for good." Kim follows Bert's instructions, and it works.

5.2 Future access to work empowerment structures by means of ICT

The solution described above delivers all relevant information where and when it is needed, which impacts the work empowerment structures at ICSE.me. In the following, we describe why we assume that easy access to all relevant information will also facilitate access to resources, support and opportunities for personal growth and learning.

5.2.1 Access to information. The shift leader assigns fault and maintenance orders to his team members. Installers get their assignments after logging in to the solution. They can see their personal dashboard with the relevant work packages uploaded. Depending on their individual knowledge and capabilities, they are able to draw targeted additional information, e.g. circuit diagrams or pictures, access routes (map view, surrounding area) or security regulations concerning the appliance to be repaired. The maintenance history (logbook with text messages and optional attached videos or pictures) provides data on previous activities.

Per name and definition, an ICT's primary task is to provide its users with information. Depending on its capabilities, this could be almost unlimited information. However, the

challenge is to make formal as well as informal knowledge accessible how and when it is needed. In the case of ICSE.me, the formal knowledge is largely represented by technical, mostly device-related knowledge, such as data sheets or routes to a particular appliance. Informal knowledge is accessible via the diverse sources of user generated content. In the machine logbook, for example, the users can see which maintenance or repair actions were carried out when and by whom. Such information helps the employees to better recognize and assess future problems themselves.

5.2.2 Access to resources. When the shift master prepares the working package briefing and sends it to his colleagues' smart devices, they get information about required tools and protective equipment. Via ICSE.me, Kim and Roland can see which spare parts are probably needed or important during their shift, make a targeted stop at the tool shop to pick up needed parts directly and put them inside their transporter. This saves the amount of time spent between receiving a fault message and resolving it.

The information provided by ICSE.me allows easy access to diverse kinds of resources. On the one hand, the function "device information" provides employees with necessary information concerning, e.g. required tools, safety equipment and possible spare parts. Further, they find out where to get everything they need. Such knowledge enables the workers to consider all important issues from the beginning of their shift, to access all relevant resources, and coordinate their work schedule accordingly. On the other hand, using ICSE.me also provides greater access to time as a resource. Support via ICT has the potential to substantially reduce the time spent from a fault message to resolution. When employees can consider all required tools, safety equipment and spare parts at an early stage of their shift, they save a lot of effort and covering the same routes twice, which gives vital access to additional time.

5.2.3 Access to support. The machine history provides not only data about previous activities but also the possibility of directly contacting people involved to ask for background information. Further, to get quick access to colleagues whose support they need, the solution provides a "Yellow Pages" section on the mobile devices of the maintenance crew. Experts who are online can be identified and directly contacted by text message, call or video call. It helps to find the right person for the right job, and even if that person is not available, it provides the profile of a colleague who can assist. ICSE.me offers different possibilities to get in touch with people who might be able to give feedback and guidance generally or for specific tasks. Not only the Yellow Pages, but also other functionalities such as the logbook functionality, allow the users to identify and contact experts and hence to get direct access to support.

5.2.4 Access to opportunities. As described above, Kim and Roland as well as their colleagues and superiors can save a lot of time using ICSE.me. Not only in the saved time, but also while they are moving around, the new system facilitates their access to opportunities for growth and mobility. First of all, ICSE.me enhances awareness in that employees can stay in touch with what their colleagues are doing. It can also enhance the awareness of what is going on in other departments or company-wide, which could draw attention to further development opportunities. Further, it offers the possibility of improving personal problem solving skills as the employees can learn while on the move and in between assignments, e.g. by looking at how problems have been solved by others. Particularly, the facilitated access to information, resources and support helps workers in finding good solutions for their upcoming tasks. Organizing and prioritizing tasks autonomously further contributes to their competencies. Finally, ICSE.me offers workers the opportunity to display their competencies company-wide.

This can happen by referring to and making public personal experience, expertise and ideas, which may be advantageous when it comes to improving their professional positions.

6. Discussion

6.1 Toward a framework for ICT-supported structural empowerment

For the context of operations management studies have found empowerment to be an important catalyzer for achieving process efficiency as well as employee satisfaction. Our results add to this research by showing how ICT that supports operations execution can enable structural empowerment.

Generalizing beyond the presented case, the framework in Figure 4 illustrates how ICT can support structural empowerment of employees in collaborative manufacturing environments with regards to the four dimensions of structural empowerment.

With regard to the access to information, ICT can help to do the preparation of manufacturing work. Templates can give guidance along best practices such as the option in the ICSE.me as similar problems can be searched quickly in advance of entering the site. This reduces search time and speeds up the fixing of a problem, as material and tools necessary for a task can be selected upfront. ICT can also help to provide information to navigate like maps to reach a site or a maintenance object faster. Pictures provided of the situation on the site allow them to detect a problem faster and more easily. Thus, employees are less dependent on co-workers' availability, can find relevant information more easily than otherwise and do not spend undue amounts of time on unnecessary routes.

ICT providing access to resources allows employees to see which spare parts are needed or important during their shift. In addition, information regarding parts is directly assigned that it reduces the risk of information overload. Thus, employees can prepare their transporters without spending time on additional routes to the inventory. ICT-support also allows them to discuss the problems without spending too much time collecting the necessary parts.

When it comes to access to support, ICT empowers employees by allowing synchronous and asynchronous communication between the maintenance workers. It helps them find the right person for the right job. Even if that person is not available, suggestions of other colleagues help. This leads to a situation in which problems can be visualized across different locations and solved remotely.

Finally, ICT gives employees access to opportunities in order to conduct individual innovation activities. For instance, workers can track the history of maintenance activities and get an overview. This empowers them to search for new solutions independently and thus also to reflect on how to solve problems and set priorities. Such learning on the job not

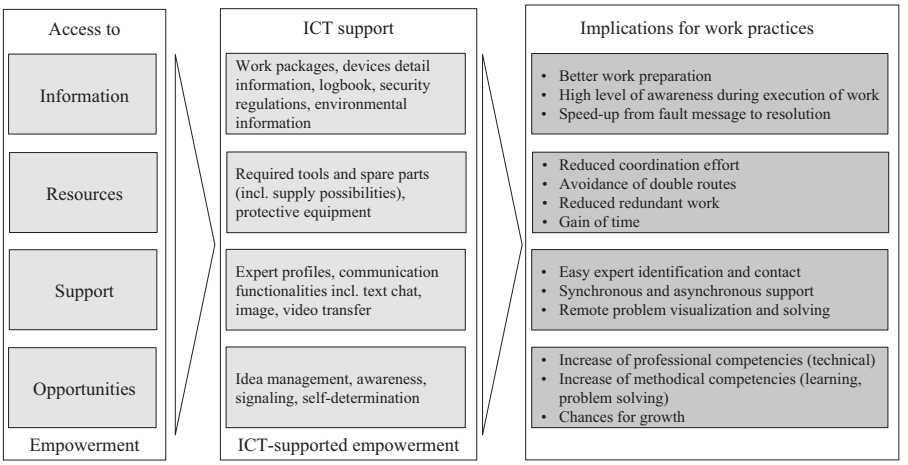


Figure 4. ICT-supported empowerment and its implications

only increases their competencies but also allows for innovation activities. ICT makes it very easy to document, share and discuss new ideas during the working daym and thus provides leverage for such innovation activities.

6.2 Practical implications

Next, we elaborate on the practical implication of ICT-supported structural empowerment, thus generalizing from our findings and discussing their broader applicability.

First of all, companies can use the above presented framework as a guideline to design individual solutions to support structural empowerment of employees in in collaborative manufacturing environments. As such, the described service characteristics can help companies to identify relevant areas in which workers can benefit from an ICT-driven empowerment.

Second, the procedure used for our study can be transferred to other situations when it comes to identifying the relevant area and the related work practices: creating problem scenarios based on the insights of the existing practices; creating activity scenarios as suggestion on how to improve the current situation; and designing a prototype and conducting an evaluation.

Third, our results provide some practical implications with regard to the four dimensions when it comes to implementing an IT system on the shop floor:

- Access to information should be supported by a system detecting the location of an employee on the shop floor and providing relevant information related to machines nearby first. Another possibility is to extract such information in relation to the task and thus a machine an employee is assigned to. The latter is relevant to provide employees with information upfront before they proceed to their operation site. To support these features digitally enabled templates should be used to give guidance along best practices, digital maps to support the navigation and context-specific pictures to allow faster and easier problem detection.
- When it comes to the access to resources, a system should be linked to the material database so that spare parts being available are up to date or that employees have the option to order directly. Another design option should include connecting mobile spare part stocks with employees so that the location of spare parts yet unused is available, e.g. allowing to contact a colleague nearby in an emergency to get a specific spare part that he/she has on the transporter for a scheduled maintenance.
- System design features regarding access to support should include a chat option with groups that are related, e.g. to specific types of machines. In addition, locations of colleagues should be visible.
- Access to opportunities should be reflected in a system's design by providing a summary of prior information regarding a machine within the chat function and allowing to add own content such as a short video or picture easily. A supervisor should be informed about suggestions automatically and everyone should be able to comment on a suggestion.

Finally, it is important to see the results of the case in the context of a shared service in a manufacturing environment with mobile maintenance teams for spatially distributed machines.

As illustrated in the scenarios, in such settings, it is paramount to provide employees with relevant information on work coordination and process execution as well as improvement. Hence, the results are applicable for other mobile shared services in manufacturing environments, but also in service environments with spatially distributed service delivery locations (e.g. bank branches with ATMs or fitness studios). Additionally, while there might be similarities to end customer related services (e.g. mobile maintenance

for heating devices), the integration of designing customer experience needs to be seen against the background of the four empowerment dimensions before being able to transfer the insights.

6.3 Theoretical implications

While we provide evidence from a particular case, general implications for theory in operations management can be deducted. First, we show how the theory of structural empowerment can support the design of an ICT to support manufacturing practices. Hence, our research is in line with Walker *et al.* (2015) by grounding improvements of operations in adequate behavioral theory. Using a scenario-based design, we prototypically implemented a worker-centric digital design that addresses the four dimensions of structural empowerment to support employees in their constantly changing workplaces. The ICT solution addresses the relevant needs of employees regarding empowerment based on the problem and activity scenarios. As such, it does not only provide access to information but also facilitates the access to resources, to support and to opportunities for growth and learning. The access to information can be seen as a basic lever, as good access to information can lead to greater availability of resources in terms of time and equipment, as well as facilitating access to support. Hence, we contribute to operations management literature (including the different concepts such as TQM, TPM, continuous improvement or lean management) by showing the role of structural empowerment theory and its application. In addition, we go beyond prior work on the role of ICT (e.g. Legner *et al.*, 2017) in addressing how all dimensions of structural empowerment can be supported.

Second, we provide a more specific understanding of how ICT can serve as an antecedent for empowerment which is important when it comes to establishing structural empowerment in organizations (Hirzel *et al.*, 2017). As such, we extend prior work that highlighted the role of ICT operations management but did not provide guiding principles (e.g. Jurburg *et al.*, 2016). In addition, we contribute to literature on structural empowerment (e.g. Laschinger *et al.*, 2004) by highlighting the role of ICT as an important antecedent as well as information systems (e.g. Legner *et al.*, 2017) by showing how ICT can contribute to empowerment in the context of shop floor.

Third, our methodological procedure applied using scenario-based designs is a new approach within the operations management literature. While designing artefacts in operations management is important (e.g. new work designs), there is not much grounding in structured approaches how to design artefacts. Hence, we provide an approach in the domain of ICT solutions for supporting operations. It proposes to gather typical scenarios within a case to create problem scenarios which are then used to develop activity scenarios to address the requirements. The scenarios can be analyzed in light of an appropriate behavioral theory which is not limited to the theory of structural empowerment.

7. Conclusion, limitations and future work

Many companies see the need for increasing their production flexibility in order to stay competitive. In this context, a specific aim is to assist their shop floor workers in problem solving and decision making, thereby empowering them. We studied the mobile maintenance team of an international industrial organization, and found that their current work situation can be improved in a number of ways by implementing an ICT solution which extends the scope of their problem solving and decision making. We implemented an ICT solution giving them better access to information, to resources, to support and to opportunities, thus structurally empowering them. Beyond applying structural empowerment theory, we were able to give rich insights into the situations before and after the deployment of the solution by using a scenario-based design approach.

As with any scientific work, our study comes along with some limitations which however provide the avenue for further research. A limitation of our study is that it is based on scenarios drawn from one single case study. While we are convinced that the problems and activities we derived are typical for the type of flexible manufacturing environments, further research which includes other cases should be conducted. Such cases should especially include services in which end customers are integrated as well as cases from the service sector with similar or slightly different characteristics. It would also be beneficial in analyzing whether there is a difference between spatially distributed objects on which such services are performed or persons (e.g. mobile care services).

In addition, the notion of structural empowerment while fitting with ICT characteristics should be extended by psychological empowerment as well. Psychological empowerment refers to the psychological experience of empowerment (Spreitzer, 1995) which also comes along with introducing structural elements related to ICT. Hence, future work should also analyze variables that might be relevant to extend our understanding of the underlying psychological mechanisms beyond our results.

Further, we do not have evaluation results of a solution according to the framework that is used in day-to-day practices. Our data collection supports its applicability and usefulness. To address this issue, further investigations should include the measurement of the four empowerment dimensions – perceived access to opportunity, support, information and resources in an individual's work setting – based on Kanter's theory of structural empowerment.

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