MASTER

Supporting job quality in manufacturing from a run-time process management perspective

Jonkmans, E.M.L.

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By

E.M.L. (Eva) Jonkmans
Student identity number 0876041

Supervisors:
dr. ir. I.T.P. (Irene) Vanderfeesten (TU/e)
K. Traganos, MSc (TU/e)
dr. D. (Dirk) Fahland (TU/e)
dr. W. (Wietse) van Dijk (TNO)
drs. M. (Marjolein) Douwes (TNO)

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Abstract

Problem The Industry 4.0 paradigm calls for the integration of human resource needs in increasingly automated manufacturing environments. One of these needs is a sufficient job quality. Currently, run-time guidance regarding job quality is missing.

Research objective The aim of this research is to design a conceptual solution which supports job quality in manufacturing processes by monitoring and controlling process activities executed by humans in a run-time environment.

Methodology The objective was reached by executing a design science research including the analysis, development and evaluation of the proposed conceptual solution. Firstly, the concept job quality was explored by means of a literature review and semi-structured interviews. After elicitation of the biggest challenges regarding job quality within the domain of manufacturing, the job quality factors related to these challenges were researched further to find possible run-time solutions which can be implemented in a BPMS. The solutions were defined as guidelines and validated by experts, after which a conceptual solution framework was created. This conceptual framework was applied to two use cases, by implementing the relevant guidelines in the software Camunda. This application was evaluated in terms of feasibility, by executing a proof-of-concept analysis, and in terms of usability, by executing semi-structured interviews with use case experts based on the Technology Acceptance Model (TAM) (Davis, 1985).

Results The first result of the research is a definition of job quality and its factors. 45 job quality factors were defined of which the factors autonomy, task variety, social isolation, physical load and time pressure were found to be challenged the most in increasingly automated and/or robotized manufacturing processes. The second result of the research is a conceptual solution framework, describing eight guidelines and twelve variables which could be implemented in a BPMS to support the five selected job quality factors. The third result is the technical implementation and evaluation of the conceptual solution framework. A demo was created in Camunda, applying five of the eight guidelines to two selected use cases. This demo was evaluated as feasible regarding the use case application. In terms of usefulness, the application to the first use case was evaluated as useful, whereas the application to the second use case was evaluated as doubtful.

Conclusion Overall, the conclusion of the research is that certain aspects of job quality in manufacturing processes *can* be integrated in a BPMS, namely by implementing guidelines and variables regarding autonomy, task variety and physical load. However, *the extent to* which such an implementation *supports* job quality depends on which job quality factor(s) will be supported by the BPMS and the context in which this implementation takes place.

Limitations and further research The main limitations of this research lie in the complexity of the concept of job quality, the usefulness of run-time job quality solutions as opposed to design-time job quality solutions, the requirements underlying the guidelines and the limited application and evaluation. The opportunities for further research lie in implementing and evaluating the other proposed guidelines, investigating possible design-time solutions, extending the physical load analysis in the demo and researching real-time measurement of job quality factors.

Keywords: job quality, business process management systems, Industry 4.0, human factors, monitoring and controlling, manufacturing

Preface

This report is the final result of the graduation project which I worked on for the last seven months in order to finalize the master's degree in Business Information Systems at the Eindhoven University of Technology. Almost seven years ago I started studying Industrial Engineering at the university in Eindhoven, and now, after many exams and group projects, I am almost graduated. It still feels a little unreal. I am very happy with the result of the project, and would like to thank a few people whose supervision and support helped me a lot to come to this result.

First of all, I would like to thank Irene Vanderfeesten, who was my first supervisor in the project. Despite her busy schedule we consistently had meetings to discuss the progress of my project and she helped me make the right decisions to move forward. She always made me feel like I was doing a great job, especially in times I felt less confident myself, which helped me keep the stress level to a minimum. Her enthusiasm and support encouraged me to work hard and to keep improving my work, which is why I think I have come so far. Thank you!

Secondly, I would like to thank Kostas Traganos and Dirk Fahland, my second and third supervisor. Kostas, your practical help with the Camunda software and feedback throughout and in the end of the project really helped me to successfully execute and report the technical part of my project, the part which I was most scared about at the start. Dirk, your feedback during and in the end of the project forced me to think critically about my research and the choices I made, which I think was really valuable for the final result.

Thirdly, I would like to thank my supervisors of TNO, Wietse van Dijk and Marjolein Douwes. They supervised me throughout the whole semester by discussing my progress, bringing me into contact with the right people for interviews and brainstorming with me. They attended my midterm presentation and have constantly been enthusiastic about my research. Also, they invited me for two relevant project meetings, which I found really interesting to attend and gave me more insights into the things currently going on in some of my research domains. Thank you both for your active involvement, it really helped in shaping my project and gaining good results.

Also, I would like to thank all interviewees from the TU/e, TNO, the Rossini project and Thomas Regout International for their time and valuable input. Both in the analysis and evaluation phase of this project, I have gained very interesting insights from the interviews. Your answers to the questions and the discussions that emerged from it really helped me to get a deeper understanding of the research areas and the implications of my solution design.

Furthermore, I would like to thank the people who were part of Irene's study group of master graduate students for their views and input during our regular meetings.

And finally, I would like to thank my boyfriend Paul, who made sure I kept my focus on the project while working from home, and also my family and friends, who all encouraged me throughout the semester and provided me with the necessary distractions and relaxation once in a while.

Eva Jonkmans
9 July 2020

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Chapter 1

Introduction

This report is about a research project regarding job quality in manufacturing processes and how job quality in these processes can be supported by means of Business Process Management (BPM) software.

BPM can be described as “a body of methods, techniques and tools to discover, analyze, redesign, execute and monitor business processes” (Dumas et al., 2013). A BPM system or BPM software (BPMS) mainly supports the BPM functions of executing and monitoring business processes. In this sense, such software is a technical solution for tasks that previously were carried out by people on a day to day basis, for example managers or team leaders. The advantage of using BPMS is that it can collect a lot of data and information during the execution of a process, and that it can ensure a certain performance within the process by managing processes with a high level of control.

The increase of the use of these kind of automation solutions is very characterizing for the current development in the manufacturing industry called Industry 4.0. Industry 4.0 is often described as the fourth industrial revolution, and refers to "the totality of the spheres of economy in which the fully automatic production processes are based on artificial intellect and the Internet create new machines without human participation." (Alekseev, Evdokimov, Tarasova, Khachaturyan, & Khachaturyan, 2018). In other words, it refers to the overall digitization of industries, where the physical tasks are executed by machines and robots, decisions are made automatically by systems and above all, the level of human participation is decreasing. Industry 4.0 is highly related to an increasing level of automation and robotization of processes in the manufacturing domain. For human workers in industrial settings, this new paradigm highly influences their way of working and their working environment. More and more tasks are performed by machines or robots. This can effect the human work positively, for example when physically heavy tasks are taken over. But it can also have a negative effect, for example when just a very simple, highly repetitive task remains in the process and a worker has to execute this task for a whole day. Sometimes people even need to work together with co-bots. A co-bot, or co-robot, is a robot which needs to work together with a human worker to complete a task. They differ in this sense from traditional robots, which are built to execute tasks independently, without human participation.

These changes call for new ways of managing manufacturing processes, and more specifically, managing both human and non-human resources in manufacturing processes. In the HORSE[1] project research has been done regarding this need. The HORSE project is a European Union Horizon 2020 project and is focused on using BPM technology to support and coordinate manufacturing processes in real-time. This was done by developing a manufacturing process management system (MPMS) which orchestrates manufacturing processes in which robots and humans collaborate (Vanderfeesten et al., 2019). The aim was to make these processes "more flexible, more efficient and more effective to produce" (Vanderfeesten et al., 2019). One of these goals is slightly related to employee well-being, since the flexibility goal refers to a more "flexible task allocation between robots and humans" (Vanderfeesten et al., 2019). However, in the evaluation of the MPMS for one of the HORSE use cases, participants complained that the system forced them to work in a certain way, and that flexibility in their jobs had decreased (Vanderfeesten et al., 2019). In this

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[1] `https://cordis.europa.eu/project/id/680734`

sense, it seems that the MPMS fails in integrating specific needs of human resources. This shows that an increasing level of automation can negatively effect the jobs that are still performed by humans, because most BPMS implementations, like the MPMS of the HORSE project, are aimed at increasing production efficiency and effectiveness, and do not integrate human resource needs successfully. Also, as described previously, the content of human jobs changes, since tasks are (partly) automated or robotized. This is where the quality of the jobs remaining for the human resources comes at risk.

Job quality often refers to the quality of the output of a job, for example in terms of a certain level of precision reached. However, this is not the kind of job quality this research is about. In this research, job quality refers to the way how work- and employment related characteristics influence the quality of a job experienced by the people who perform this job. One of the goals many organizations have is to improve job quality. Also, maintaining a suitable level of job quality when implementing innovative technical automation and robot solutions has become a priority in several research projects, since it now becomes clear that Industry 4.0 technologies have a high risk of lowering the job quality of shop floor workers. There are multiple perspectives from which this problem can be approached, for example job design, ergonomics or work- and organizational psychology. In this research, the main focus will be to explore possibilities of tackling this problem from a business process management perspective.

This new way of approaching job quality challenges is a relevant subject to study for two main reasons: Firstly, automation, robotization and implementing BPMS within manufacturing processes can have many advantages, like a higher efficiency, which the HORSE project has shown. Therefore, it is worthwhile to investigate how to maintain, or even increase, the job quality experienced by humans, instead of lowering it, when such technical solutions are implemented. Secondly, solutions from the job design or ergonomics perspective are not always an option. An example is one of the use cases in the HORSE project, where a robotic solution was found for a manual task with a high level of physical strain, but this robotic solution was too expensive to implement. (Vanderfeesten et al., 2019). In these cases, it is valuable to search for job quality solutions from a different perspective. This research therefore has the following objective:

Research objective

The aim of this research is to design a conceptual solution which supports job quality in manufacturing processes by monitoring and controlling process activities executed by humans in a run-time environment.

Report structure This report consists of the following chapters: Firstly, the motivation, problem statement and main research question of this research are described in Chapter 2. Secondly, the background of the research areas discussed in this introduction are described in more detail in Chapter 3. This includes an introduction to the domains of Industry 4.0, business process management and human factors. Thirdly, the different phases of this research are described in the methodology (Chapter 4), including the sub research questions and the methods applied to answer these sub research questions. The next chapter (Chapter 5) contains the analysis results regarding the definition and exploration of the concept job quality. Subsequently, the results regarding the conceptual solution design are discussed in Chapter 6. The results of applying and evaluating this conceptual solution in practice are presented in Chapters 7 and 8. The report ends with the final chapter (Chapter 9) containing the main conclusion of the research, the research limitations and possibilities for further research.

Chapter 2

Problem Definition

In this chapter, the problem statement, main research question and sub research questions of this research are discussed.

2.1 Problem statement

In the introduction chapter the subjects related to this research were discussed briefly. Within these research areas, several challenges and knowledge gaps exist, which lead to the aim of this research. First of all, in manufacturing, the jobs and work of people are changing due to the Industry 4.0 revolution. Research is needed on how to successfully manage this new way of working. Such research is done for example in the Rossini[1] project, a Horizon 2020 project in which a human-robot collaboration platform is developed (Rossini, 2019). This changes the work of people, because tasks are taken over by robots, or must be performed in collaboration with robots. This puts the job quality experienced by the workers at risk. Secondly, applying business process management (BPM) in order to maintain a certain level of job quality has not been researched thoroughly. BPM is often mostly focused on increasing efficiency and decreasing costs, while it could also be beneficial in terms of job quality. Companies often overlook human factors in their BPM-approach, or manage job quality separately from process management. It is therefore worthwhile to investigate if human factors can be integrated in BPM, and if this would improve job quality. Polderdijk already showed that it is possible to analyze human physical strain from a BPM perspective in design-time (Polderdijk, 2017), but no run-time solutions were proposed yet. Thirdly, it is valuable to extend the existing research regarding physical strain and business process management to other job quality factors than just physical strain. For example, factors like mental strain, autonomy in the job and skill development might also have an effect on the overall quality of a job.

Since research is still needed in these different directions, this research is relevant for both practical, and scientific purposes. Based on these challenges, the following problem statement was defined:

The Industry 4.0 paradigm calls for integration of human resource needs in an increasingly automated working environment. One of these needs is a sufficient job quality. Polderdijk's BPMN extension and design tool is useful for analyzing physical strain on a process level. This tool however does not take other job quality factors than physical strain into account, and also does not provide solutions, improvements or run-time guidance to problems regarding job quality in processes. Therefore, an implementation of solutions in the run-time environment of processes is required in order to maintain or even increase job quality.

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[1] `https://cordis.europa.eu/project/id/818087`

2.2 Main research question

Based on the problem statement, the following main research question was defined:

Main research question
How can job quality in manufacturing processes be supported by monitoring and controlling process activities executed by humans in a run-time environment?

2.3 Sub research questions

In order to come to an overall conclusion regarding the main research question, the seven sub research questions listed below were defined and researched. These sub research questions were created and categorized based on the phases of the problem-solving cycle (PSC) (van Aken & Berends, 2018). The PSC and the sub research questions will be discussed in more detail in Chapter 4.

1. What is job quality?
2. Which job quality factors should be taken into account in this research?
    (a) What are the challenges in increasingly automated and/or robotized manufacturing processes regarding job quality?
    (b) Which job quality factors are related to business process management?
3. Which guidelines would be useful to be implemented in a BPMS to monitor and control the selected job quality factors?
4. Which variables would be useful to be implemented in a BPMS to monitor and control the selected job quality factors?
5. How can the guidelines and variables be merged into a conceptual solution framework for supporting the selected job quality factors by monitoring and controlling process activities executed by humans in a run-time environment?
6. How can the conceptual solution framework be implemented and applied in practice?
7. Is the application of the conceptual solution framework feasible and/or useful?
    (a) Is it feasible to implement the job quality guidelines in a BPMS?
    (b) Is it useful to implement the job quality guidelines in a BPMS?

The next chapter elaborates further on the subjects of business process management, Industry 4.0 and human factors in order to get a better understanding of the theoretical background and relevance of this research.

Chapter 3

Theoretical Background

As described in the introduction, the research proposed in this report is about monitoring and controlling job quality in manufacturing processes, especially in an increasingly automated and robotized environment. Multiple topics from different domains are relevant and overlapping in this research. First of all, monitoring and controlling business processes is part of the business process management domain. This research domain is focused on solving business problems by modeling, (re)designing, implementing and analyzing business processes. One phase within business process management is monitoring and controlling, which basically means that certain factors of processes are measured (monitoring) to keep track of the performance of a process, and that these measures are used to manage the execution of the process (controlling). This execution and controlling of the process typically happens by means of process models, which are discussed in more detail later in this chapter. The second topic is job quality, which is part of the human factors domain. This domain focuses on the interaction between systems and people, and how human factors can be integrated in systems. Job quality research focuses on what makes a good job, or in other words, which factors increase or decrease the quality of jobs. The last topic describing the context of this research, is automation and robotization as part of the era of Industry 4.0. An increasing level of automation and robotization is an upcoming development in multiple industries, of which one is the manufacturing domain. The overall term to describe this development is Industry 4.0, which also includes smart factories, digitization and other recent technical developments.

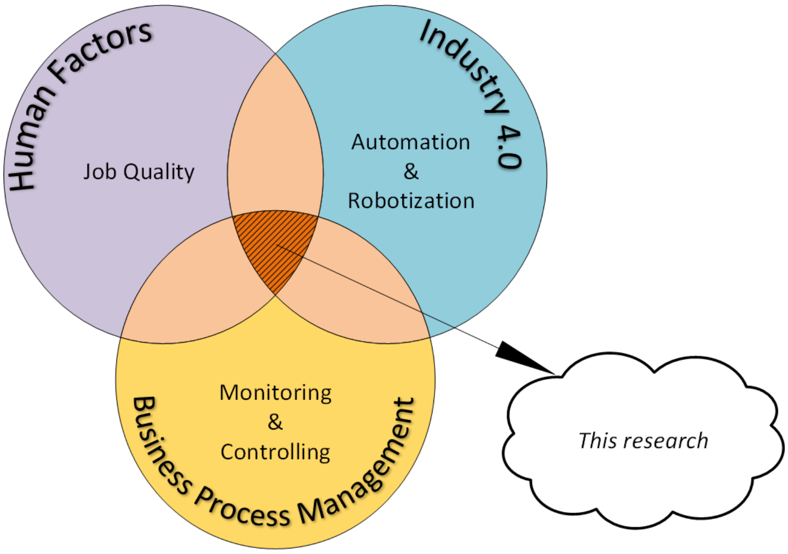

Figure 3.1: Venn diagram of the topics determining the context of this research.

The combination of two different scientific domains, namely business process management and human factors, researched within the context of Industry 4.0, is very interesting to investigate. The three domains and topics are shown in the Venn diagram in Figure 3.1. How these topics and domains apply more specifically to this research, is described in more detail in the rest of this chapter.

Some projects which have inspired this research are currently executed regarding one or more of the domains in Figure 3.1. These projects will be discussed throughout this chapter. Also, this research will take place in collaboration with TNO, an organization which is currently researching job quality in the Rossini project.

3.1 Business Process Management

Multiple definitions regarding the term Business Process Management exist, one of them already mentioned in the introduction by Dumas and colleagues, namely “a body of methods, techniques and tools to discover, analyze, redesign, execute and monitor business processes” (Dumas et al., 2013). Business Process Management (BPM) is a continuous activity in organizations, and the way BPM is executed can be explained by the BPM lifecycle. This lifecycle is shown in Figure 3.2. The goal of BPM is to continuously improve business outcomes by means of improving business processes. Improvement in this context can be for example to increase efficiency, improve product quality, decrease costs or decrease throughput time.

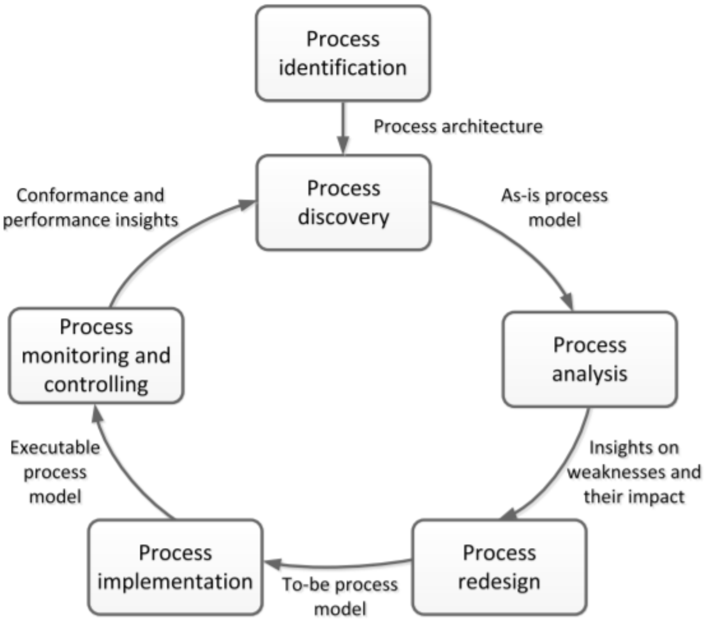

Figure 3.2: The BPM lifecycle (Dumas et al., 2013)

The activities described in the BPM life cycle are ordered in a cyclic way: for the same process or the same organization, the steps cannot and should not be executed just once. Firstly, a process must be identified (process identification), in other words, the existence of a certain process is acknowledged. After this, the process activities, the relations between the activities and other characteristics of the process are discovered (process discovery), which is often visualized in a process model. One very common process modeling standard is the Business Process Model and Notation (BPMN), which is used for modeling processes in all kinds of organizations (Chinosi & Trombetta, 2012). When a process has been discovered, the process is analyzed (process analysis), and then improved by redesigning the process (process redesign). An example of a redesign practice is task elimination, which means a task is completely eliminated from a process (Reijers & Mansar, 2005). This is shown in Figure 3.3. The fifth phase of the cycle is to implement the redesigned process (process implementation). After implementation of the new process, the execution of the new process will start. This can happen in two ways: the process is simply changed and executed in the new way, or the process model of the new process is made executable and implemented in a so-called Business Process Management System (BPMS). The BPMS takes care of the enactment of the executable process model and once the process is running, the BPMS also supports the monitoring and controlling of the process.

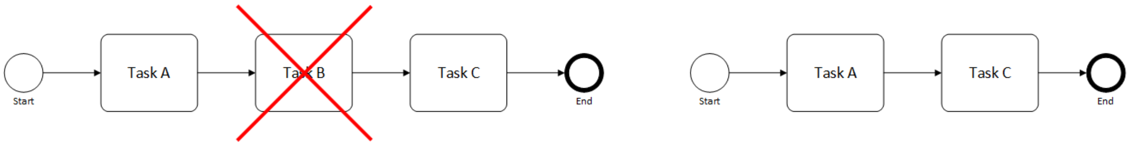

Figure 3.3: Example of task elimination.

This last way directly leads to the last phase of the BPM life cycle, namely the 'Process monitoring and controlling' phase. This phase will be the focus of this research, since measures to monitor and control rules regarding job quality will be implemented in BPM software. Process monitoring an controlling is supported by a BPMS in the following way: A BPMS automatically supports and "executes" processes based on process models implemented in this BPMS. A simple example to explain this is an administration process. The process starts for example with the activity "Write report". A BPMS sends this activity to the responsible actor of the process, who receives the task, performs it, and finally finishes it. After the BPMS receives a signal that the activity is finished, the BPMS goes back to the process model, finds the next activity or activities in the process, and sends assignments for these activities to the responsible actors of those activities. An example in the administration process would be that the activity "Sign report" is forwarded to the supervisor. Such a system records a lot of data which can be valuable for business process management. The system can for example record how much time is performed on certain tasks or what the throughput time is of a process. This is why BPMS's play a highly important role in the process monitoring and controlling phase, since they collect a lot of data regarding processes which can indicate whether a process is executed efficiently.

Another relevant aspect of BPMS's for this research is the ability to enforce rules through a BPMS. Not only can a BPMS gather and measure data regarding certain factors, it can also automatically make decisions regarding the results of this analysis and enforce rules in a process. In this way, the BPMS orchestrates the process, automatically allocating tasks to the right actors, and adapting factors based on measurements to ensure a certain performance, or in the case of this project, a certain level of job quality. In addition to ensuring a certain performance level in this way, a BPMS can also ensure that business processes are executed as they were predefined, instead of being executed as an employee at that moment thinks best (Dumas et al., 2013).

All in all, by means of a BPMS, data regarding the process are collected and analyzed (monitoring). During this analysis, problems are identified, and corrective actions are undertaken (controlling) (Dumas et al., 2013). Both the analysis and the following corrective actions can happen in design-time, in which case the collected monitoring data is analysed and these results are used to re-design the process. Or, the monitoring and controlling happens in run-time, in which case analysis is performed during the execution of the process and corrective actions are taken in real-time as well. Interesting data to collect can be the throughput time of a process or the total costs. In this research the focus is job quality, how to monitor and control factors regarding job quality in run-time and how to enforce rules supporting job quality.

3.2 Industry 4.0

Industry 4.0 is a term which is often used to describe the fourth industrial revolution. After the mechanization (first revolution), the more intensive use of electrical energy (second revolution) and the more widespread digitization (third revolution), we arrived at the age of Industry 4.0 (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014). There is not, one clear definition for the Industry 4.0 concept. Piccarozzi and colleagues tried to define Industry 4.0 based on previously written literature on the subject, and found that the definitions can be divided by domains, of which the technical definition/components category is the most detailed (Piccarozzi, Aquilani, & Gatti, 2018). An example definition from this category is "Industry 4.0 is the totality of the spheres of economy in which the fully automatic production processes are based on artificial intellect and the Internet create new machines without human participation" (Alekseev et al., 2018). In other words, it refers to the overall digitization of industries, where the physical tasks are executed by machines and robots, decisions are made automatically by systems and above all, the level of human participation is decreasing. Industry 4.0 is related to many innovations, for example smart factories, smart manufacturing and the Internet of Things. A smart factory can be defined as "a manufacturing solution that provides such flexible and adaptive production processes that will solve problems arising on a production facility with dynamic and rapidly changing boundary conditions in a world of increasing complexity" (Radziwon, Bilberg, Bogers, & Madsen, 2013). This definition leaves room for a lot of imagination, but in practice, the smart factory concept is often strongly related to a high level of automation by means of combining innovative software, hardware and/or mechanics solutions. Also, it often leads to less and less involvement of humans in the manufacturing processes. Smart manufacturing is very similar to the smart factory concept, since it refers to the way innovative new technologies are used to improve production environments. Kusiak defines the concept of a smart factory as "an emerging form of production integrating manufacturing assests of today and tomorrow with sensors, computing platforms, communication technology, control, simulation, data intensive modelling and predictive engineering" (Kusiak, 2017). Another booming concept within Industry 4.0 is the Internet of Things (IoT). This term refers to the way how devices, technologies, data, services and many other innovative solutions are all connected. Trying to grasp all aspects of this concept, it can be defined as "a conceptual framework that leverages on the availability of heterogeneous devices and interconnection solutions, as well as augmented physical objects providing a shared information base on global scale, to support the design of applications involving at the same virtual level both people and representations of objects" (Atzori, Iera, & Morabito, 2016). The new paradigm of Industry 4.0 changes the way of working within the manufacturing domain, and therefore calls for new ways of managing manual work within production processes.

BPM in the era of Industry 4.0 As described previously, a BPMS collects and analyzes measurements in order to optimally allocate tasks to resources. An example of this is the research by Erasmus and colleagues on ability-based resource allocation. In this research, they focused on specifying activities and human abilities in a BPMS, in order to allocate rsources to activities during process run-time (Erasmus et al., 2018). This kind of technology is extremely interesting in environments with a high level of automation and/or robotization. Firstly, in most cases a high level of automation also means more data is collected regarding all kinds of measures. If there is more data available, a BPMS can make decisions based on more than just a few measurements, making the decisions more efficient and valid. Secondly, in case of robotization, a BPMS must allocate tasks not only to human resources, but also to robots. This new division of labour can either be beneficial or disadvantageous for the job quality of human resources, and it is therefore worthwhile to investigate how a BPMS should make this division and other decisions regarding tasks taken over by robots. This is also supported by another research by Erasmus and colleagues, where they investigated integrating the concept of unified process management in the manufacturing domain. They found that BPM can help to increase the integration and flexibility of manufacturing operations in their research within the HORSE project. (Erasmus, Vanderfeesten, Traganos, Keulen, & Grefen, 2020).

The HORSE[1] project is a project which focuses on tackling these kinds of problems in Industry 4.0 settings with a BPM approach. The HORSE project is a European project funded by the European Union's Horizon 2020 research and innovation programme, and has been running for the past four to five years. The project aims to propose a new flexible smart factory model for the manufacturing industry to make the collaboration of humans, robots, AGV's (Autonomous Guided Vehicles) and machinery more efficient (HORSE, 2017). The project has a number of partners, of which two are the university of technology in Eindhoven and TNO. The TUE (Tecnical University of Eindhoven) has focused on the business process management context of the HORSE project. They

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[1] `https://cordis.europa.eu/project/id/680734`

built a Manufacturing Process Management System (MPMS) that orchestrates both the horizontal and vertical integration of manufacturing processes, including activities like the coordination of tasks, availability of resources and exception handling (TU/e, 2019). Together with most of the project partners, TNO has focused on the HORSE Framework for the HORSE project, which contains new knowledge and tools regarding the management and cooperation between humans, robots and digital support, like augmented reality in the working space (TNO, 2019a).

3.3 Human Factors

Another domain within this research is the human factors or ergonomics domain, which can be defined as "the study of how humans behave physically and psychologically in relation to particular environments" (Rouse, 2005). Part of this research lies within this domain, since the first phase is to examine which challenges currently exist in increasingly automated and robotized environments, regarding different factors of job quality (which could be physical or psychological factors).

Job quality is a subject discussed in multiple scientific domains, like economics, social sciences and psychology. Numerous definitions and indicators for a high or low job quality exist. Examples of such indicators are pay, skill, autonomy and job satisfaction (Findlay, Kalleberg, & Warhurst, 2013). Although job quality does not have one generally accepted definition, the subject has definitely gained more attention in the last decade, especially among policy-makers, whose goal is not just to increase the quantity of jobs, but also the quality (Findlay et al., 2013). This goal has emerged due to the potential impact of job quality on individual, firm and national well-being (Clark, 2015). At the firm level, job quality can increase worker productivity and employee engagement. In turn, a higher employee engagement leads to, among others, lower turnover and lower absenteeism (Clark, 2015). On the other hand, a low job quality, for example due to a high level of physical strain in the job, can lead to unhealthy employees, and a higher level of turnover and absenteeism. Therefore, job quality, and especially how to increase job quality, is a relevant topic to investigate.

This research is focusing on job quality in the context of manufacturing processes in the era of Industry 4.0. Therefore, regarding human factors, this research also relates a little bit to human-technology interaction (HTI), since currently, the interaction between humans and different forms of technology is both increasing and changing in the manufacturing industry. HTI is a field which focuses on the interaction between humans and information technology, and the design of computer technology (Carroll & Kjeldskov, 2013). The main focus of this research is not the interaction between humans and computers, but it will slightly touch upon the subject of which challenges regarding job quality might have arisen in manufacturing by new forms of human-technology interaction. Therefore, HTI is not one of the main research domains of this research, but it is worth mentioning in this theoretical background section.

The integration of human factors in BPM Business Process Management is often related to increasing efficiency or decreasing costs, but the way processes are managed also highly influences humans and how they experience work. For example, managing processes through a BPMS often makes process execution more rigid and less flexible, which could negatively effect the job quality for human resources. As described before, BPM and Industry 4.0 are related by the increasing availability of measurements by automation and the division of labour between human and robotic resources. This leads to several research opportunities related to incorporating human factors in BPM. It is worthwhile to investigate if it is even possible to take human factors into account in BPM, and if this is the case, how this should be done. This kind of research could lead for example to insights regarding the measurements of human factors within a BPMS, or to insights on how to optimally allocate labour amongst human and non-human resources. Also, the impact of applying BPM principles on human resources would be an interesting research subject. These are all suggestions which show the relevance of researching human factors and BPM together. Within the HORSE project, a research was executed by Polderdijk regarding the integration of human factors in Business Process Management of manufacturing processes, more specifically regarding the integration of human physical risk factors.

Polderdijk designed a tool for modeling human physical risk factors in BPMN process models of manufacturing processes. Her research was performed in cooperation with TNO. Physical risk factors are related to physical strain that people experience during their working activities. Physical strain is also part of job quality, since often the level of physical strain directly or indirectly influences the experienced overall job quality. An example is the research by Yoo and colleagues which shows that physical stress and job stress are correlated (Yoo et al., 2017). Polderdijk created a tool in MS Visio[2] which integrates the existing human risk analysis method of TNO with the modeling of process activity elements of BPMN (Polderdijk, 2017). The tool enables a process designer to assess the physical risk of each activity in a process and visualize the results on the activity elements in the process model (Polderdijk, 2017). This BPMN extension was evaluated as useful for visualizing and analyzing human physical strain in manufacturing processes (Polderdijk, 2017). An example of the use of the extension is shown in Figure 3.4. In this figure, a process model in the BPMN language is shown, which includes one human activity. This activity was evaluated with the TNO checklist[3] and contains a physical risk regarding one of the nine categories defined by the TNO checklist, namely a risk due to hand-arm tasks. The extension only shows the categories for which physical risks are found, and not the more detailed problems or the level 2 analysis by other, more specific tools. Also, the tool can only be used to model and visualize a process, but not to support the process during enactment, nor to monitor and control the physical risks identified at design-time.

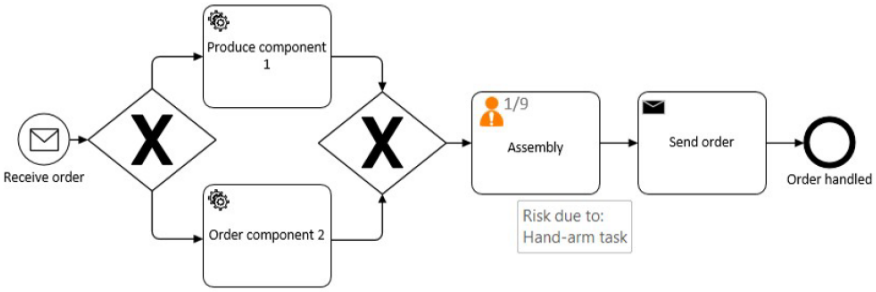

Figure 3.4: Example application of the physical risk BPMN extension (Polderdijk, 2017)

3.4 Research initiatives regarding job quality and BPM in Industry 4.0 settings

Robotization and automation has changed a lot regarding the way processes are designed and managed, and possibly also the way this impacts the job quality experienced by human resources. Insights into this problem and the way it should be dealt with is limited, and therefore it is useful to research. How can processes be managed in such a way that job quality is ensured, even in the age of Industry 4.0? Some projects already investigate parts of this question. The SHOP4CF[4] project, which is the successor of the HORSE project, will focus more on human factors in process management as compared to the HORSE project. Another project integrating these three subjects is the Rossini Project, in which TNO is involved.

TNO is an independent research organization, which focuses on innovations in nine different domains (TNO, 2019b). One of these domains is "Healthy living" and is focused on promoting healthy working and living (TNO, 2019b). Especially the area of healthy working is interesting in this case, since this research is about supporting job quality. TNO contributed to the previously discussed HORSE project and Polderdijk's graduation project. TNO also contributed to this research, by sharing their knowledge regarding physical strain as part of job quality, and their findings regarding job quality in the currently running Rossini project.

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[2] `https://www.microsoft.com/en-ww/microsoft-365/visio/flowchart-software`

[3] `https://www.fysiekebelasting.tno.nl/en/`

[4] `https://cordis.europa.eu/project/id/873087`

The Rossini[5] project is a European-wide Horizon 2020 project, just like HORSE, regarding human-robot cooperation in manufacturing. The aim of the Rossini project is to develop a disruptive, inherently safe hardware-software platform for the design and deployment of human-robot collaboration (HRC) applications in manufacturing. The project has been running since October 2018 and many partners from different countries in Europe are working separately on different parts of the project. TNO is one of them and is responsible for researching job quality. One of the objectives of the project is to increase job quality by efficiently managing the human-robot environment which the partners are building. There are four distinct lines of research in the project, of which one is human-robot mutual understanding (Rossini, 2019). This mutual understanding should increase flexible production and improve job quality. In the first phase of their research, TNO already developed a framework regarding job quality, containing the different dimensions of job quality. In the second phase, a design-time tool was built to model job quality in process models. In this way, it is easy to see where in a process problems regarding job quality exist. The next step, which is moving process management from design-time to run-time, is executed by a different partner in the project. Consequently, research to find what kind of monitoring and control rules should be incorporated regarding job quality in order to support a certain job quality level, is highly relevant in this context.

To conclude, manufacturing environments are becoming increasingly automated and/or robotized, while in manufacturing processes, still tasks for human resources remain. The job quality for the workers performing these tasks is at risk due to the changing nature of these processes. Some research already focused on using BPM as an approach to analyze job quality problems in processes. Also, in the HORSE project, implementing Business Process Management Software (BPMS) was found to make the management of manufacturing processes more flexible. However, run-time BPM solutions regarding job quality are missing. This research is therefore highly relevant, since it could lead to valuable insights regarding the integration of job quality in the run-time BPM approach of increasingly automated and/or robotized manufacturing environments.

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[5] `https://cordis.europa.eu/project/id/818087`

Chapter 4

Methodology

This chapter describes the methodology of the research. First, the overall research phases and theory behind these are described. Then, for each research phase, the sub research questions, methods applied and deliverables are discussed.

4.1 The problem-solving cycle & design-science research

In this research, the steps of the problem-solving cycle as described by Van Aken and his colleagues were followed (van Aken & Berends, 2018). This cycle is shown in Figure 4.1 and consists of five phases, which can be repeated by defining a new problem based on the evaluation results. This research goes through the cycle one time, and suggestions for further research are done based on the evaluation results.

Table 4.1: Design science research guidelines (Hevner et al., 2004)

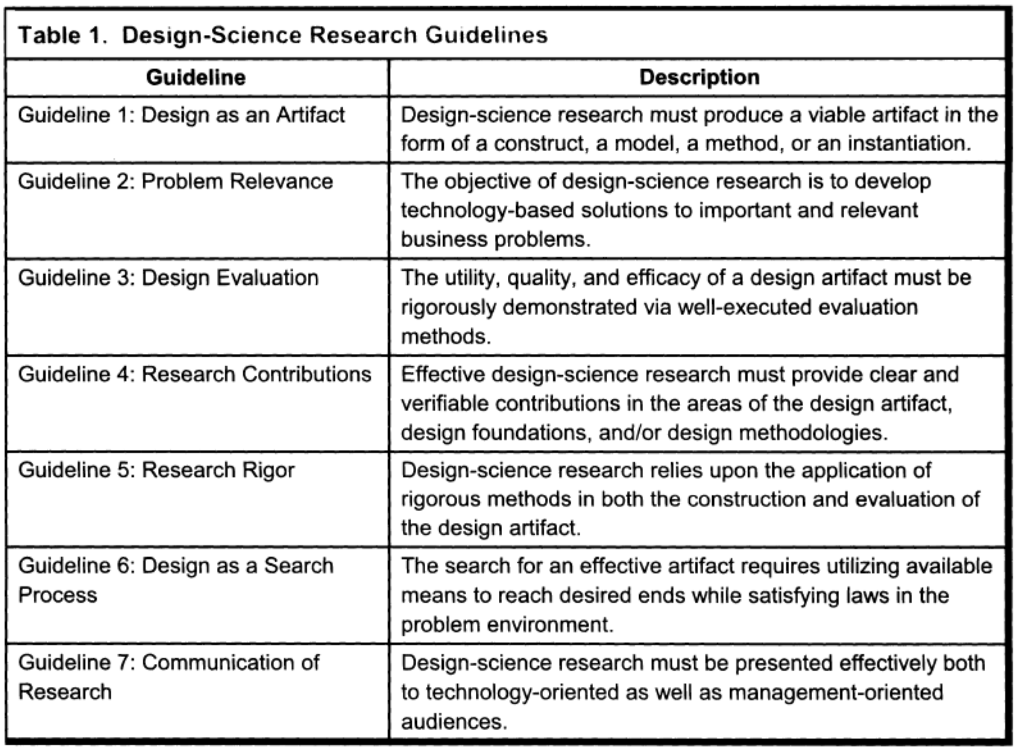

Table 1. Design-Science Research Guidelines

Guideline	Description
Guideline 1: Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Guideline 2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
Guideline 5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

Although the main steps executed during this research are described by the problem-solving cycle, the design science research principles of Hevner are taken into account as well. According to Hevner, there are seven guidelines which should be followed when performing design science research (Hevner et al., 2004). These guidelines are presented in Table 4.1. The goal of this research is to design a conceptual solution, and therefore it belongs to the field of design science research, making Hevner's guidelines highly applicable. For each of the research phases described in the PSC in Figure 4.1, methods, activities and deliverables were defined and structured according to the principles of design science research. Which guidelines of Table 4.1 are applicable to which phase is shown in Figure 4.1. In the rest of this Chapter, the relation between the phases and the guidelines, and how the methods used in the research fit the guidelines, are explained in more detail.

4.2 Sub research questions, methods and deliverables

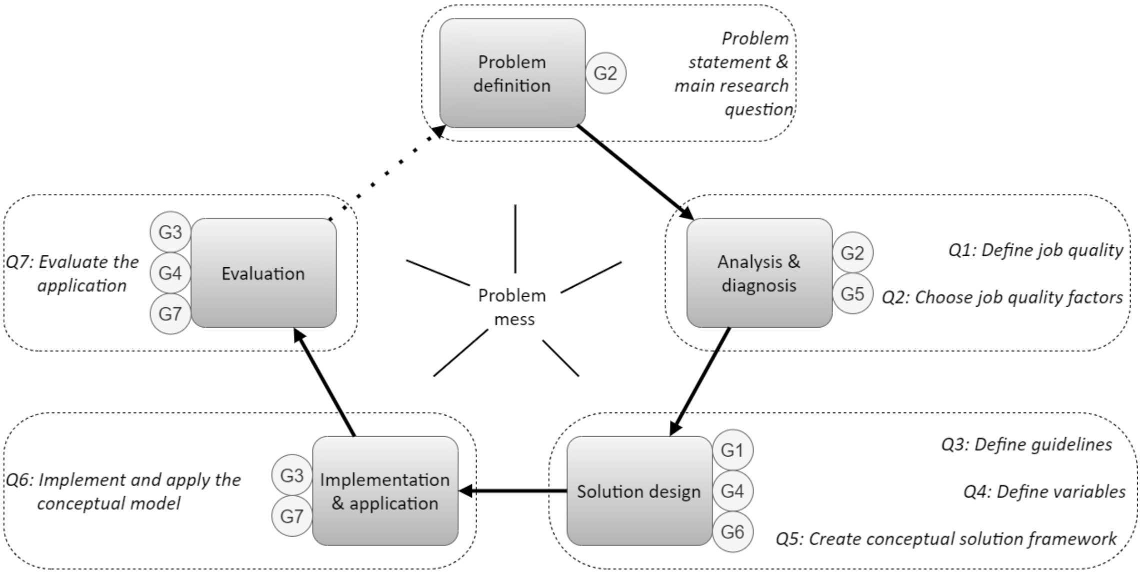

Figure 4.1: The problem-solving cycle phases (van Aken & Berends, 2018), design science research guidelines (Hevner et al., 2004) related to them (the numbers in the small circles refer to the guidelines in Table 4.1) and the sub research questions.

Seven sub research questions were defined for this research. These are all related to different phases of the problem-solving cycle, as shown in 4.1. Regarding each phase in this cycle, also the relevant design science research guidelines which were taken into account during the execution of this phase, are listed. This is shown in Figure 4.1 as well.

The problem definition phase was already executed by defining a problem statement and a main research question in Chapter 2. The sub research questions and the methods and steps executed to answer them are described in more detail in the next sections. For each research question, also a deliverable is described.

4.2.1 Analysis and diagnosis

This section describes the sub research questions, methods applied and deliverables produced in the analysis and diagnosis phase of this research. In this phase, guideline 2 regarding problem relevance and guideline 5 regarding research rigor, as described in Table 4.1 were taken into account. Guideline 2 is relevant in this phase because the goal is to find the current job quality challenges in manufacturing, in order to make sure that important and relevant business problems are addressed by the solution design. Guideline 5 is relevant because it is important to apply rigorous methods during this phase to come to a well constructed conceptual design in the next phase of this research. Figure 4.2 at the end of this section shows an overview of the questions, activities and deliverables of this research phase.

Q1: What is job quality?

Methods: Literature research and semi-structured interviews.
This question was researched in two ways: Firstly, a thorough literature research was executed on research already performed regarding the factors and dimensions of job quality. The literature research protocol followed to do this is shown in Appendix A. Secondly, during semi-structured interviews, interviewees with different relevant backgrounds were asked which factors they think are part of job quality. The questions in the interviews used to define job quality are questions 2, 3 and 4 in the questionnaire in Appendix B. Literature research and semi-structured interviews were used since these are scientific methods and are therefore in line with Guideline 5 of Hevner (see Table 4.1). The overlap in the literature and interview findings was then used to create a suitable definition of job quality. This two step method regarding the definition of job quality is a decision based on research by Bustillo and colleagues, who claim that it is best to first derive information from social sciences literature, and then ask workers what they think is important for job quality when defining job quality (Muñoz de Bustillo, Fernández-Macías, Esteve, & Antón, 2011). In this case, the opinions of experts instead of workers were collected. These experts have knowledge regarding different aspects or perspectives of job quality, which is sufficient for this purpose, since the goal in this phase of the research is to get a very broad view of job quality. Six experts were interviewed, of which three work- and organizational psychologists, two ergonomists and one human factors engineer. Most of these experts are also currently, or have been in the past, involved in projects related to manufacturing companies. The steps executed within the research regarding the definition of job quality are also shown in Figure 4.2.
D1: A definition of job quality and a structured list of job quality factors.

Q2a: What are the challenges in increasingly automated and/or robotized manufacturing processes regarding job quality?

Methods: Semi-structured interviews.
In semi-structured interviews, experts were questioned on the different kinds of job quality challenges in (smart) manufacturing environments. These questions were part of the same interviews with the same experts as described in the methods section of Q1. The interviewees were asked what they think are the biggest challenges regarding job quality in manufacturing, by asking them questions 5, 6, 7, 9, 10 and 12 of the questionnaire in Appendix B. Not all questions were asked to all interviewees, based on how complete their answers to previous questions were or on how much time was left in the interview. The expertise of the interviewees lies in different dimensions, for example the ergonomists can tell more about the physical challenges, while the work- and organizational psychologists can tell more about the mental demands on the workers. Despite the diversity in backgrounds of the experts, the same questions were asked to each interviewee, since the questions are general enough to be answered from different perspectives. Also, the focus was on how the increase in automation and/or robotization might lead to a change in jobs for human workers, and eventually the rise of new job quality challenges. These challenges were researched in order to make a valid and relevant selection of job quality factors to investigate further, which is in line with Guideline 2 of Hevners design-science research principles, as stated in Table 4.1.
D2a: A list of challenges.

Q2b: Which job quality factors are related to business process management?

Methods: Brainstorm.
Based on own insights and knowledge of the business process management domain, possible BPM solutions or improvements were elicited and considered regarding each job quality factor of the list in D1. If no BPM-related solution could be found regarding a job quality factor, this job quality factor was not considered regarding the selection of job quality factors included in the conceptual solution framework.
D2b: A list of job quality factors which are related to managing business processes, also describing how BPM could potentially help to improve these factors.

Q2: Which job quality factors should be taken into account in this research?

Methods: Analysis of D2a and D2b based on own insights. A decision had to be made which job quality factors were going to be taken into account in the solution design phase and which were not. This decision was partly based on which factors are relevant to focus on, which are the factors related to the challenges listed in D2a. The decision was also based on which factors could potentially be managed or improved by means of Business Process Management (BPM), which are the job quality factors listed in D2b. The following steps were performed to arrive at a valid selection: Firstly, the challenges in D2a were linked to the different job quality factors in D1. Secondly, the challenges (and their corresponding job quality factors) mentioned most often in the interviews were selected. Lastly, this selection was compared to the list of BPM-related job quality factors of D2b. The factors which were not on this list or solely lend themselves for design-time solutions, were ruled out. By applying these steps, the most important and relevant job quality factors were selected in accordance to Guideline 2 of Table 4.1.
D2: A list of job quality factors which are included in the solution design phase of the research.

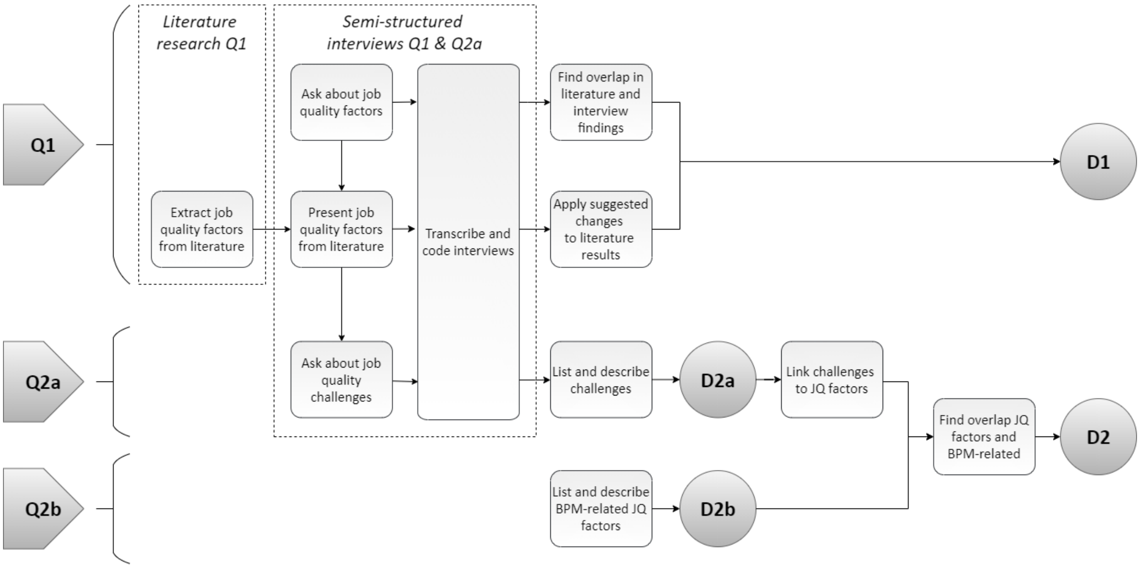

Figure 4.2: Research steps within the analysis and diagnosis phase

4.2.2 Solution design

The research steps performed in the solution design phase of the research are shown in Figure 4.3 at the end of this section. The steps regarding research question 3 and 4 take into account Guideline 4 and Guideline 6 of Hevner as described in Table 4.1, while the research regarding question 5 takes into account Guideline 1.

Q3: Which guidelines would be useful to be implemented in a BPMS to monitor and control the selected job quality factors?

Methods: Semi-structured interviews, literature research and expert opinion.
In order to find which guidelines should be implemented in a BPMS to support the job quality factors selected in D2, results from the interviews and information from other (literary) sources was used to create a first list of possible guidelines. The questions asked during the semi-structured interviews to collect these ideas are questions 8, 11, 14 and 15 of the questionnaire in Appendix B. If for a job quality factor no suitable guideline could be found, an idea regarding a guideline based on own insights was presented. This first list of ideas was evaluated during a discussion with two experts (an ergonomist and a human factors engineer). After this discussion, the best ideas were

selected, the proposed changes were applied, and the final list of guidelines was created.
D3: A list of guidelines.

Q4: Which variables would be useful to be implemented in a BPMS to monitor and control the selected job quality factors?

Methods: Semi-structured interviews and analysis of D3.
After deciding which job quality factors and guidelines are relevant and show potential, it is important to decide which variables must be supported by the BPMS, either in design-time or run-time. The variables which are included in the model were based on D2, which shows which job quality factors are relevant, ideas collected during the interviews and the (intermediate) results of Q3, which show which guidelines are taken into account. This is also shown in Figure 4.3. During the interviews ideas regarding the variables were collected by asking question 13 of the questionnaire in Appendix B to the interviewees. After collecting the potential list of variables, this list was compared to the output of the expert discussion described in the methods section of Q3. This lead to a final list of variables.
D4: A list of variables.

Q5: How can the guidelines and variables be merged into a conceptual solution framework for supporting the selected job quality factors by monitoring and controlling process activities executed by humans in a run-time environment?

Methods: Combine D2, D3 and D4.
After finding which guidelines and variables to implement, the next question is how these are related and should be combined and executed in a run-time environment. To answer this research question, Guideline 1 of Hevner regarding design science in information systems research as shown in Table 4.1 was followed. In this case, the artifact produced is a conceptual solution framework. The framework shows what should be implemented in a BPMS in order to support job quality. The framework brings the domains of job quality and BPM together by connecting specific job quality factors to specific BPMS guidelines and variables. The job quality factors were defined by D2, the guidelines by D3 and the variables by D4.
D5: A conceptual solution framework showing the relations between the job quality factors, the BPMS guidelines and the variables.

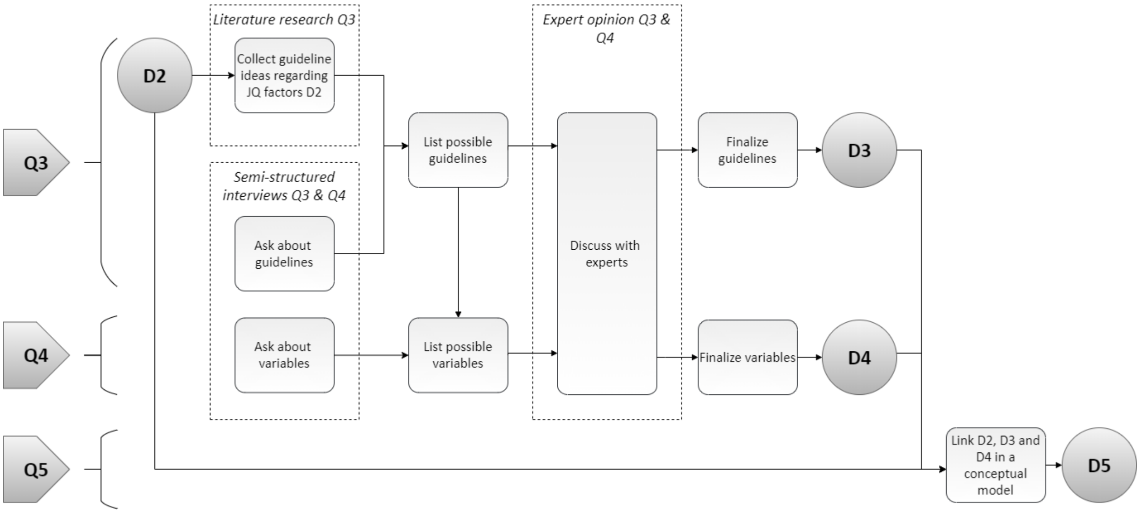

Figure 4.3: Methodology of the solution design phase

4.2.3 Implementation, application & evaluation

At the start of this research phase, two use cases were selected to perform the implementation, application and evaluation on. Only the parts of the conceptual solution framework of D5 which were relevant for the selected use cases were implemented. Therefore the goal was to select use cases in such a way that as many guidelines as possible were implemented, applied and evaluated. For each use case, the research steps as described in Figure 4.4 at the end of this section were executed. Regarding this phase, Guidelines 3, 4 and 7 of Table 4.1 were followed.

Q6: How can the conceptual solution framework be implemented and applied in practice?

Methods: Building a demo.
To answer this sub question, parts of the previously designed conceptual solution framework of D5 were implemented in the BPM software Camunda[1]. This software is able to deal with creating BPMN process models and executing these process models. Camunda has an open-source version which allows easy communication between the Camunda engine and Java classes, which is useful when implementing the logic behind the guidelines. Also, standard functions of Camunda, like the Camunda modeler, can be extended, which is useful when implementing variables. After selection of the guidelines which would be implemented, based on two use cases, for each guideline more detailed functionalities were defined. This is useful for evaluating the design later on, in line with Guideline 3 of Table 4.1, and communicating the way the implementation works to the audience, in line with Guideline 7 of Table 4.1. After this, the variables and logic behind these functionalities were implemented, until the behaviour of the Camunda software met the functionalities described before.
D6: A demo applying the selected parts of the conceptual solution framework described in D5 to two use cases.

Q7a: Is it feasible to implement the job quality guidelines in a BPMS?

Methods: Proof-of-concept.
The previously described application is firstly evaluated in terms of functionalities: the goal of the application is to implement the previously defined guidelines in a successful way, and therefore in this part of the evaluation, the goal is to test whether it is indeed *possible* to implement the guidelines in a BPMS. Guideline 3 of Table 4.1 is taken into account while performing this evaluation. To evaluate this, a dummy scenario is described for each use case in which situations occur regarding all functionalities described in Q6. In this way, it is tested whether indeed, the functionalities are met, and therefore the guidelines were successfully implemented.
D7a: A run through an example scenario (both screencast and report) and assessment whether the functionalities were met.

Q7b: Is it useful to implement the job quality guidelines in a BPMS?

Methods: Semi-structured Interview.
The second part of the evaluation is to find whether it is useful to implement such guidelines in BPMS software. This is in line with Guideline 4 of Table 4.1 which is related to the contributions of the design to the relevant research area. To evaluate this, for both use cases, a use case expert was selected and an interview was planned. During this interview, a questionnaire based on the Technology Acceptance Model (TAM) was used to find the ease of use, perceived usefulness and intention to use of such an application (Davis, 1985). This is in line with Guideline 3 of Table 4.1, which states that well-executed evaluation methods need to be executed. Normally the Technology Acceptance Model is used to obtain quantitative results from a big group of respondents. However, this was not possible within the scope of this research, and therefore the TAM statements where used in a qualitative way, in order to find what the interviewee thinks of the application in terms of different usefulness dimensions. Also, some open questions regarding the strengths and weaknesses of the application were discussed. The questionnaires used for the usefulness evaluation are shown in Appendices I and J. During the interviews, it was stressed that this application is a demo, and that the question we really want to answer is, if it would be useful to implement these guidelines in a BPMS on a much bigger scale and in a more extensive way.
D7b: A qualitative evaluation regarding the usefulness of the application.

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[1] `https://camunda.com/`

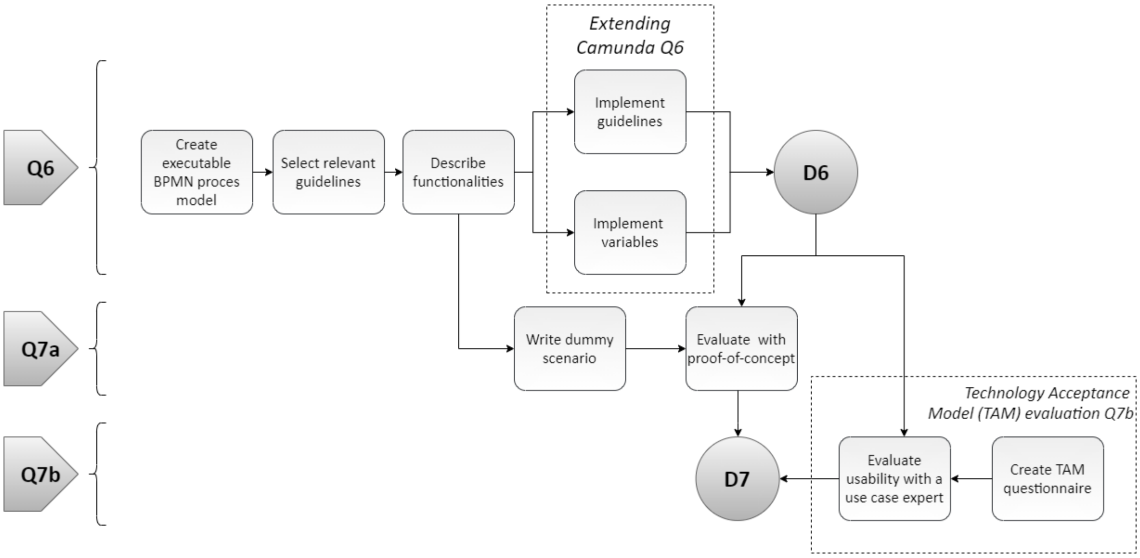


Figure 4.4: Methodology of the implementation, application and evaluation phase.

Chapter 5

Job quality

This chapter describes the results regarding the definition of job quality and the selection of job quality factors to consider in the design of the conceptual solution framework. The final overall job quality definition is as follows:

Job quality is a multidimensional concept covering the extent to which multiple characteristics of work and employment lead to employee well-being.

Based on this definition, a tree-like structure was created showing the dimensions and work- and employment characteristics related to employee well-being, and therefore job quality. This result is shown in Figure 5.1. The figure shows which factors, within different organizational levels and different categories, are related to job quality. The three levels are the constitutional, organizational and job level, and in total 45 job quality factors were found within these levels. The Figure works as follows: The highest level is the level "job quality", which constitutes all categories and factors related to this concept. When going one level down, the concept of job quality is decomposed into three categories namely constitutional characteristics, organizational characteristics and job characteristics. The constitutional characteristics level consist of work-related characteristics on a country- or state level, like the existence of unions and employment related laws. Going down one level to one organization within the country or state, the organizational characteristics are defined. These consist of work-related factors which are determined on an organizational level, like the wages and the career opportunities the workers within the organization get. Lastly, the job characteristics level, which refers to one job within an organization, describes the work-related factors within the job. Examples are the variety of skills someone needs to perform in a job, or the meaningfulness of a job. Within these three levels some job quality factors are also clustered in one category. The most extensive example of this categorization is the category "job demands" within the job characteristics level, which in turn is also decomposed into three categories, namely physical demands, cognitive demands and emotional demands.

In Figure 5.1, the job quality factors which were selected to be included in the conceptual solution framework, namely autonomy, task variety, social isolation, physical load and time pressure, are highlighted. These job quality factors were selected because they were found to be the most relevant in relation to current challenges in the manufacturing and Industry 4.0 domain.

The overall definition of job quality, the overview of related factors and the selection of relevant job quality factors are the main results of the analysis and diagnosis phase of this research as shown in 4.1. This was done according to the methodology described in Section 4.2.1 of Chapter 4.

In the rest of this chapter, the reasoning, steps and intermediate results leading to these main results are discussed in more detail. These intermediate results consist of exploring different job quality definitions (D1), job quality challenges (D2a), BPM-related job quality factors (D2b) and selecting the job quality factors for the conceptual solution framework (D2).

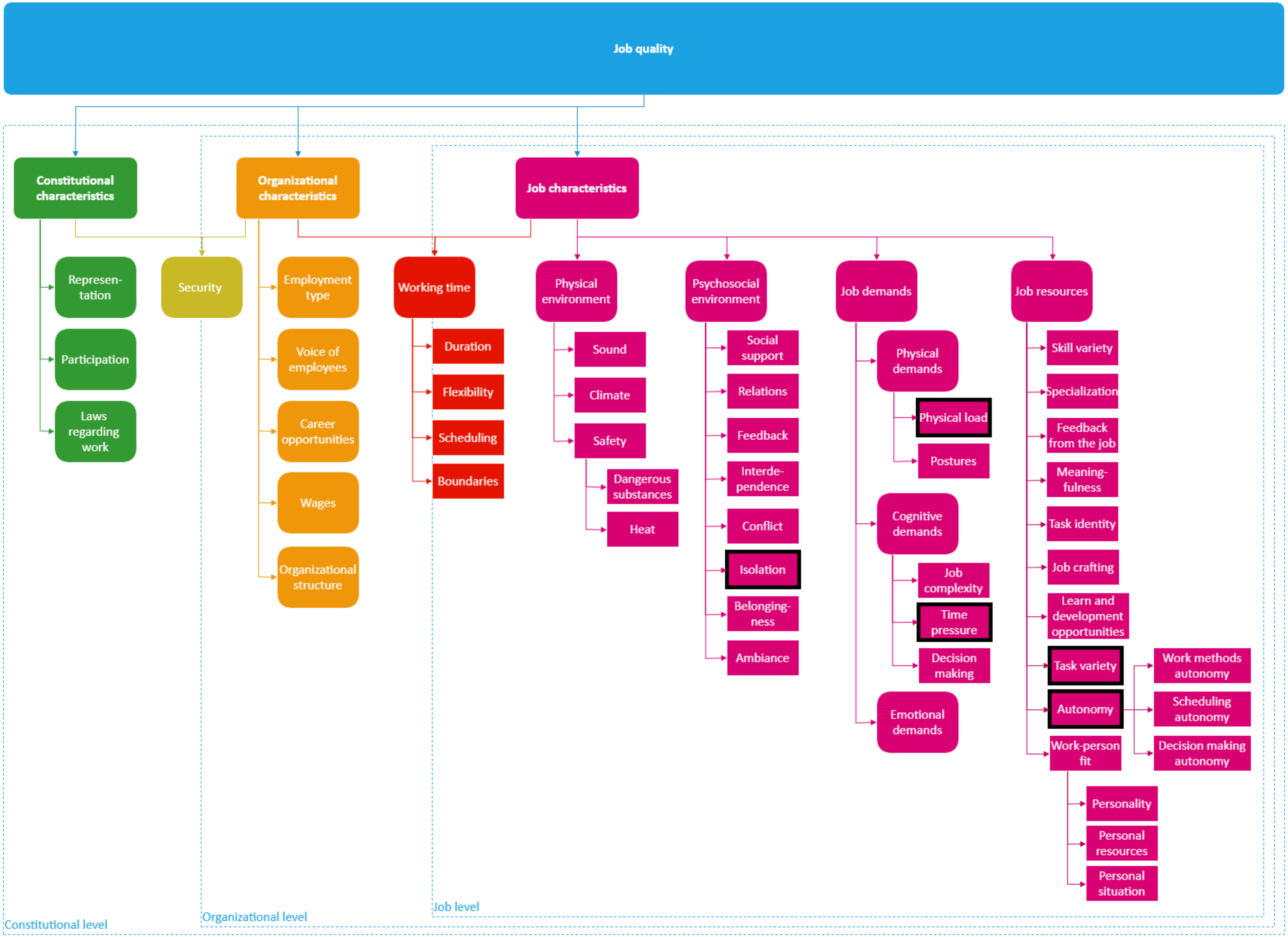


Figure 5.1: The final result regarding the definition of job quality (D1) and the selection of job quality factors (D2)

5.1 Job quality definition

In order to define job quality and produce the first deliverable (D1), a literature research and semi-structured interviews were combined. The results of the literature research are presented first, followed by the interview findings, and how they were finally merged with the literature findings into the overall definition of job quality and its factors as presented in Figure 5.1.

5.1.1 Job quality from literature

During the literature research, some issues around the concept of job quality, and how it should be defined, arose. Eventually, the findings were combined into one broad definition of job quality, as well as a decomposition of job quality into multiple factors. When using the term "job quality factors", this refers to the different factors of work which lead to a higher or lower job quality.

Job quality definitions In literature, some clear definitions of job quality were found. Holman defines job quality as "the extent to which a job has work and employment-related factors that foster beneficial outcomes for the employee, particularly psychological well-being, physical well-being and positive attitudes such as job satisfaction" (Holman, 2013). Another definition of job quality is that job quality is "constituted by the features of jobs that meet workers' needs from work" (Green & Mostafa, 2012). Eurofound also underlines the multidimensional character of job quality and stresses that different policy agendas and scientific disciplines are focused on different dimensions of job quality (Eurofound, 2020). They also claim that job quality consists of all work and employment characteristics that have been proven to have a causal relationship with well-being and health.

When comparing these different definitions, some similarities in them appear:

- Job quality has a multidimensional character
- Job quality is related to work- and employment-related characteristics
- Job quality leads to employee well-being.

These claims regarding job quality were use to create the overall definition of job quality described in italic at the beginning of this chapter. However, this overall definition was not enough regarding the purpose of this research. To find the right run-time solutions for the manufacturing and Industry 4.0 domain, a more extensive analysis was needed to understand the different dimensions and work- and employment related characteristics involved in job quality. The results of this analysis are discussed in the rest of this section.

Job satisfaction as an indicator of job quality Some researchers argue that job quality and its characteristics could be defined, or at least be indicated by, job satisfaction. If a worker experiences a high level of job satisfaction, isn't this the same as experiencing a high job quality? This approach uses an indirect way to measure job quality in order to avoid the difficulties of dealing with multiple dimensions and factors. Instead of measuring the input leading to a certain level of job quality (job characteristics), the output (worker well-being), or at least an indicator of worker well-being, namely job satisfaction, is measured (Muñoz de Bustillo et al., 2011). The advantage of that approach is that it highly simplifies defining, measuring and analyzing job quality. But multiple shortcomings make it unsuitable as an indicator of job quality, according to de Bustillo and colleagues (2011). For example, many other factors are related to the experienced level of job satisfaction, that have nothing to do with job quality. Also, using just one simple indicator is an extremely limited way to measure job quality, too limited for both policy and scientific purposes (Muñoz de Bustillo et al., 2011). Therefore, that approach of defining and measuring job quality is rejected in this research.

Multidimensionality of job quality Job quality is a multidimensional concept, which makes it hard to define and measure job quality in a universal way. Findlay and colleagues claim that "job quality is a multidimensional phenomenon" and that job quality "depends on a large number of characteristics of one's work and working conditions" (Findlay et al., 2013). They also discuss how "multiple factors and forces operating at multiple levels influence job quality" (Findlay et al., 2013). This multidimensionality of job quality is taken into account in many models and frameworks. One example worth mentioning here is the Organization for Economic Cooperation and Development (OECD) Job Quality Framework, which was used to define job quality in the Rossini Project. Other interesting models regarding job quality are the job demands-resources model and the job characteristics model. These models are about work design, which is a concept focused on job quality on an individual level, rather than on an overall job quality level regarding, for example, all jobs in a country. The framework and the models are now discussed in more detail.

The OECD Job Quality Framework

In 2015, the Organization for Economic Cooperation and Development (OECD) presented the OECD Job Quality Framework (Cazes et al., 2015). In this framework, they take into account the multidimensional character of the concept job quality and they identify which factors can be used to measure these different dimensions. They defined three domains: Earnings quality, labour market security and quality of the working environment (QWE). Also, they suggest indicators for these three dimensions. This is done in both objective and subjective ways (surveys). The dimensions and their indicators are shown in Figure 5.1. The OECD Job Quality Framework was used in the Rossini project to define job quality and to create a basis for the evaluation of job quality. In the Rossini project, the decision was made to solely focus on the QWE dimension of job quality.

Table 5.1: The OECD Job Quality Framework dimensions and their indicators (Cazes et al., 2015)

Dimensions	Indicators
Earnings	**Headline indicator: Earnings Quality**
	- Average Earnings - Earnings Inequality
Labour Market Security	**Headline indicator: Labour Market security against unemployment**
	- Unemployment risk - Unemployment insurance
	Headline indicator: Labour Market security against extreme low-pay *(a)*
	- Probability of falling into extreme low-pay
	- Probability of getting out of extreme low-pay
Quality of the Working Environment	**Headline indicator: Job strain**
	Job Demands
	- Time pressure at work - Physical health risk factors
	Job Resources
	- Work autonomy and learning opportunities - Workplace relationships
	Supplementary indicator: Working very long hours

The Job Demands-Resources Model

An important model in literature regarding worker well-being and the factors related to this is the Job Demands-Resources Model (Bakker & Demerouti, 2007). This model is shown in Figure 5.2. In the model two types of job characteristics are distinguished: job demands and job resources. Job demands are the parts of the job that cost a worker energy, and can be subdivided into physical, cognitive and emotional demands. Job resources are characteristics of a job that give the worker the tools and energy to meet the job demands. The balance between these job demands and job resources then lead to two possible outcomes: on the positive side, a worker can experience work engagement (motivation in Figure 5.2), and on the negative side a worker can experience burnout (strain in Figure 5.2). The amount of engagement and burnout experienced, lead to organizational outcomes, which also include worker well-being (Bakker & Demerouti, 2007). When using this model in job quality research, the different job demands and job resources can be presented as the job characteristics leading to a high or low job quality.

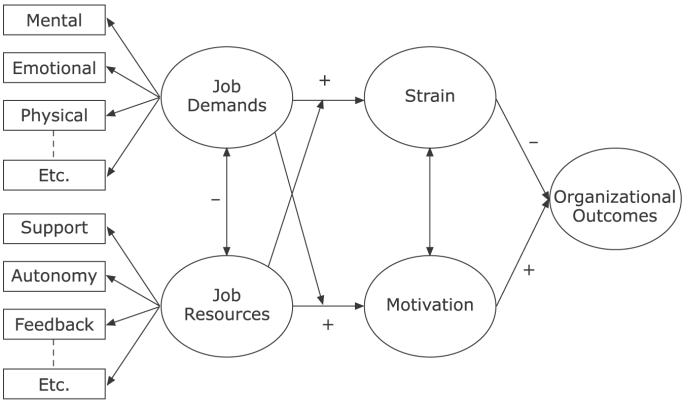


Figure 5.2: The Job Demands-Resources Model (Bakker & Demerouti, 2007)

The Job Characteristics Model

The Job Characteristics Model is a work design model created almost half a century ago in 1976 by Hackman and Oldham. Although it is quite old, it is still a very influential model in the work design literature, and many extensions and alterations have been proposed since. The original model is shown in Figure 5.3 and contains five core dimensions of a job: skill variety, task identity, task significance, autonomy and feedback (Hackman & Oldham, 1976). These core dimensions lead to psychological states and these states in turn lead to personal and work outcomes, among which work motivation and job satisfaction. A meta-analysis was performed on work-design literature by Humphrey, Nahgrang and Morgeson, in order to extend this model with other dimensions influencing the outcomes (Humphrey, Nahrgang, & Morgeson, 2007). Among other sources, this extension was used to define the job quality factors in this research, as described later in this chapter.

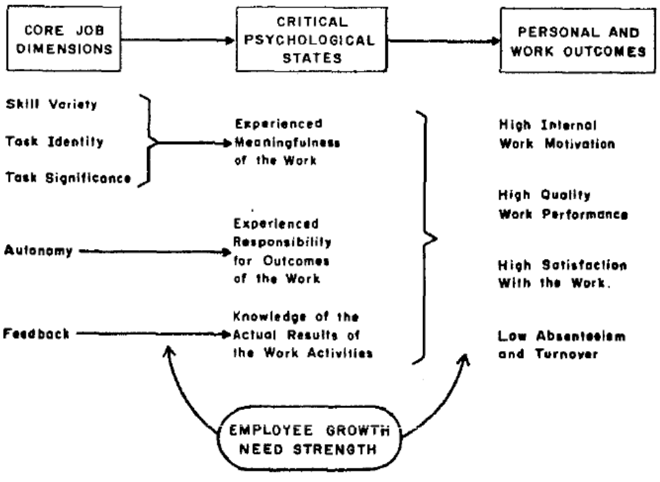


Figure 5.3: The Job Characteristics Model (Hackman & Oldham, 1976)

Because of the multidimensional character of job quality it was decided to further investigate which dimensions or factors are related to job quality. The results of this investigation are presented in the remaining part of this section. Also, the resulting job quality factors were structured according to different levels, since Findlay and colleagues stress the importance of analyzing job quality factors at different levels, such as the organizational or institutional level (Findlay et al., 2013).

5.1.2 Job quality factors from literature

In order to define which job quality factors exist, a literature research regarding job quality indicators, job quality frameworks and work design models was performed. Based on this research, eight journal articles regarding different dimensions and factors which are related to job quality were selected. The literature review protocol followed to obtain these eight reports is described in A. Three of these eight reports are the journal articles regarding the previously discussed OECD Job Quality Framework, the Job Demands-Resources model and the Job Characteristics Model. The selected articles are listed from newest to oldest publications, in Table 5.2.

Table 5.2: Selected articles in literature research regarding job quality. In case the article or report was published in a different medium than a journal, the journal impact factor was not included.

Nr	**Author(s)**	**Year**	**Title**	**JIF (2018)**	**Citations**	**Reference**
1	Cazes, Hijzen & Saint-Martin	2016	Measuring and Assessing Job Quality: The OECD Job Quality Framework	-	55	(Cazes et al., 2015)
2	Green, Mostafa, Parent-Thirion, Vermeylen, van Houten, Biletta & Lyly-Yrjanainen	2013	Is job quality becoming more unequal?	1.779	96	(Green et al., 2013)
3	Holman	2013	Job types and job quality in Europe	3.043	189	(Holman, 2013)
4	Osterman	2013	Introduction to the special issue on job quality: What does it mean and how might we think about it?	1.779	70	(Osterman, 2013)
5	De Bustillo, Fernández-Macias, Esteve & Antón	2011	E pluribus unum? A critical survey of job quality indicators	3.016	129	(Muñoz de Bustillo et al., 2011)
6	Leschke, Watt & Finn	2008	Putting a number on job quality? Constructing a European Job Quality Index	-	52	(Leschke, Watt, & Finn, 2008)
7	Humphrey, Nahrgang & Morgeson	2007	Integrating Motivational, Social, and Contextual Work Design Features: A Meta-Analytic Summary and Theoretical Extension of the Work Design Literature	4.643	1853	(Humphrey et al., 2007)
8	Bakker & Demerouti	2006	The Job Demands-Resources model: state of the art	1.547	7517	(Bakker & Demerouti, 2007)

After selecting the articles in Table 5.2, the information needed to define and structure different characteristics of job quality was extracted and processed as described in the literature review protocol in Appendix A. The result is shown in Figure 5.4. In this tree-like structure, the collected job quality factors are organized according to different levels and subcategories of job quality. For each job quality factor, the numbers show which reports of Table 5.2 are the source of this job quality factor.

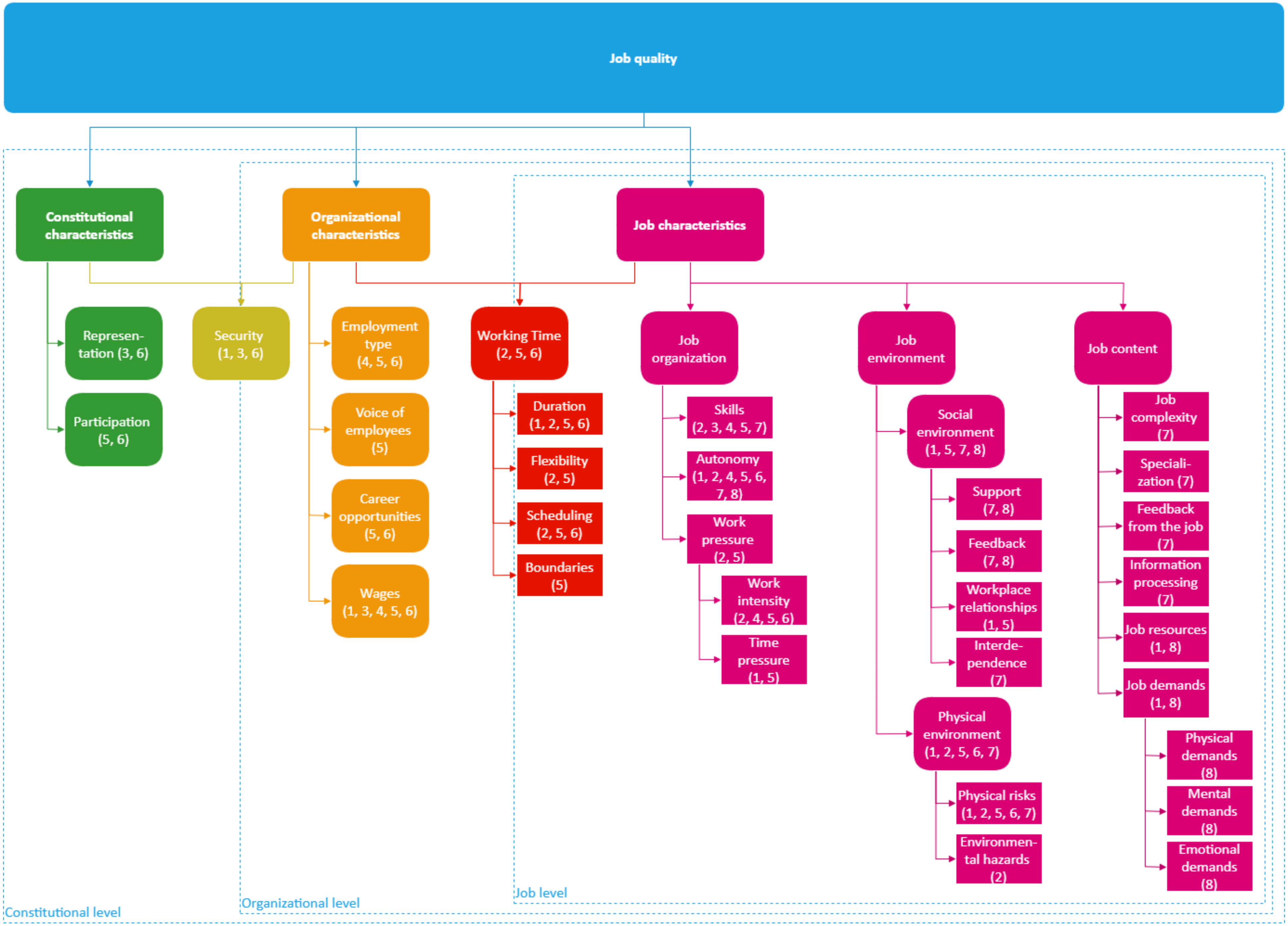


Figure 5.4: The job quality factors found in the literature research.

5.1.3 Job quality in interviews

To validate and enhance the previously described result of the literature review in Figure 5.4, semi-structured interviews were executed. Two questions were asked to the interviewees *before* showing them the literature research results, namely:

- Which factors do you think affect the experience of a high or low job quality?
- Do you know any models/frameworks regarding job quality, or which are related to this subject?

These are questions 2 and 3 of the questionnaire in Appendix B. The answers to the questions were transcribed and coded. The answers to the first question lead to a list of 53 codes containing job quality factors. The exact codes and their descriptions are shown in Appendix C. These codes were linked to the similar job quality factors already in the tree based on literature findings. This resulted in the network in Appendix D. The job quality factors that were not in the (literature-based) tree yet, were added to the tree to complete the overview of job quality factors. The answers to the second question did not lead to any new models or frameworks important for the definition of job quality, so these answers were not used to redefine the original findings based on the literature research. Also, the interviewees were asked to review the results of the literature research by asking them question 4 of the questionnaire in Appendix B:

- When you look at this model, do you think it is complete? Or do you think there are still some things missing?

This question was asked *after* showing the literature results as shown in Figure 5.4. This lead to the following findings regarding the literature-based model:

- None of the job quality factors are wrong or unnecessary, so none of the factors needs to be deleted from the model.
- Not everyone liked the structure of the model. Interviewee 2 suggests to structure the job content characteristics according to the job demands-resources model, and then the job factors according to the job characteristics model into job resources and job demands. Interviewee 4, 5 and 6 described a categorization used in their workplace, using the categories physical environment, psycho-social environment or load, physical load and cognitive-perceptive load. These restructuring suggestions were used in the new model.

All in all, the interviews led to an addition of job quality factors to the literature list, and some restructuring of the literature-based model. This led to the final definition of job quality and its factors (D1) as presented at the beginning of this chapter in Figure 5.1.

5.2 Job quality challenges

In this section, the results from the semi-structured interviews regarding the job quality challenges (D2a) are presented. The goal of the interview questions was to find relevant job quality factors in two categories within the scope of this research: relevant job quality factors regarding challenges within manufacturing processes and relevant job quality factors regarding challenges of increasingly automated and/or robotized processes. The interviews were transcribed and coded, as described in the results section regarding D1. For this research question, three code groups were created: `"JQ challenges manufacturing relevant"`, `"JQ challenges automation/robotization relevant"` and `"JQ challenges other relevant"`. Each code within such a code group refers to a job quality challenge named by one or more of the interviewees within the category of the code group. All in all, a total of 51 challenges were collected from the interview transcriptions, of which 19 challenges regarding manufacturing, 35 challenges regarding automation and robotization and one challenge regarding a subject outside these two categories. The total of all categories is higher than 51 since some codes were mentioned as challenges both regarding manufacturing processes and automated/robotized processes. The complete list of the codes regarding the challenges (D2a) is shown in Table E.1 in Appendix E. The Table contains a short description of each challenge related to the code, as well as the code group(s) to which it belongs. An example is the challenge "Monotonous work", which means the work becomes more repetitive and boring, with a low level of variety. This is a challenge both in manufacturing and in increasingly robotized/automated processes.

5.3 BPM-related job quality

In order to list the job quality factors which are related to Business Process Management (BPM), or which can be influenced from a BPM perspective, each job quality factor shown in Figure 5.1 was evaluated. If the factor is decided to be BPM-related, it was added to the list of BPM-related job quality factors (D2b), including a description of the way it could potentially be influenced by design-time or run-time BPM solutions. If the factor is evaluated as not BPM-related, the factor is not added to the list. The final list consists of 22 job quality factors. The results are shown in alphabetical order in Table F.1 in Appendix F. The Table describes whether the job quality factor could potentially be supported in design-time and/or run-time, and what kind of BPM-related improvement this support could be. An example of the Table is the job quality factor "Conflict", which could potentially be influenced by both design-time and run-time solutions. A design-time solution would be to only design tasks which can be executed alone, so no cooperation is needed and workers cannot get into a conflict. A run-time solution would be to never let workers who often get into conflict work on a task together.

5.4 Selection of job quality factors

To select the job quality factors which should be taken into account for the conceptual solution framework (D2), the previously discussed results regarding the challenges (D2a) and BPM-related solutions (D2b) were combined. This is done according to the steps described in Chapter 4 in Section 4.2.1. The first step was linking the challenges listed in Table E.1 in Appendix E to the job quality factors described in Figure 5.1, which results in the network in Figure 5.5. Sometimes this was very obvious, for example the challenge "Physical heavy workload" was linked to the job quality factor "Physical load". Sometimes a link needed a little more thought, for example the challenge "Higher control" is indirectly linked to the job quality factor "Autonomy", since a higher level of control often leads to a lower level of autonomy within the job. Some challenges were not challenges regarding specific job quality factors, and were therefore categorized as either "Overall job quality factors" or "Work design related challenges".

Since it is very likely that a challenge is mentioned multiple times by one interviewee, only the number of interviewees that mentioned a challenge is taken into account, not the number of times a challenge is mentioned within one interview. The selected challenges in Figure 5.3 were all mentioned in at least three of the six interviews. The job quality factors related to these challenges are based on the network in Figure 5.5.

Table 5.3: Challenges named in at least three out of six interviews

Challenge code	**Related JQ factor**	**Nr of interviews**
Lower autonomy	Autonomy	6
Less social interactions	Isolation	5
Monotonous work	Task variety	4
Physical heavy workload	Physical load	4
Design process from technology perspective	Work-design related challenge	3
Time pressure increases	Time pressure	3

To finalize the list, the challenge "Design process from technology perspective", was removed from the selection, based on the fact that this challenge does not have any related run-time solutions or improvements. The other five job quality factors lend themselves for run-time BPM improvements, as described in Table F.1. Therefore, the final five job quality factors which were selected to be included in the conceptual solution design (D2), as highlighted in Figure 5.1 at the beginning of this chapter are autonomy, isolation, physical load, task variety and time pressure.

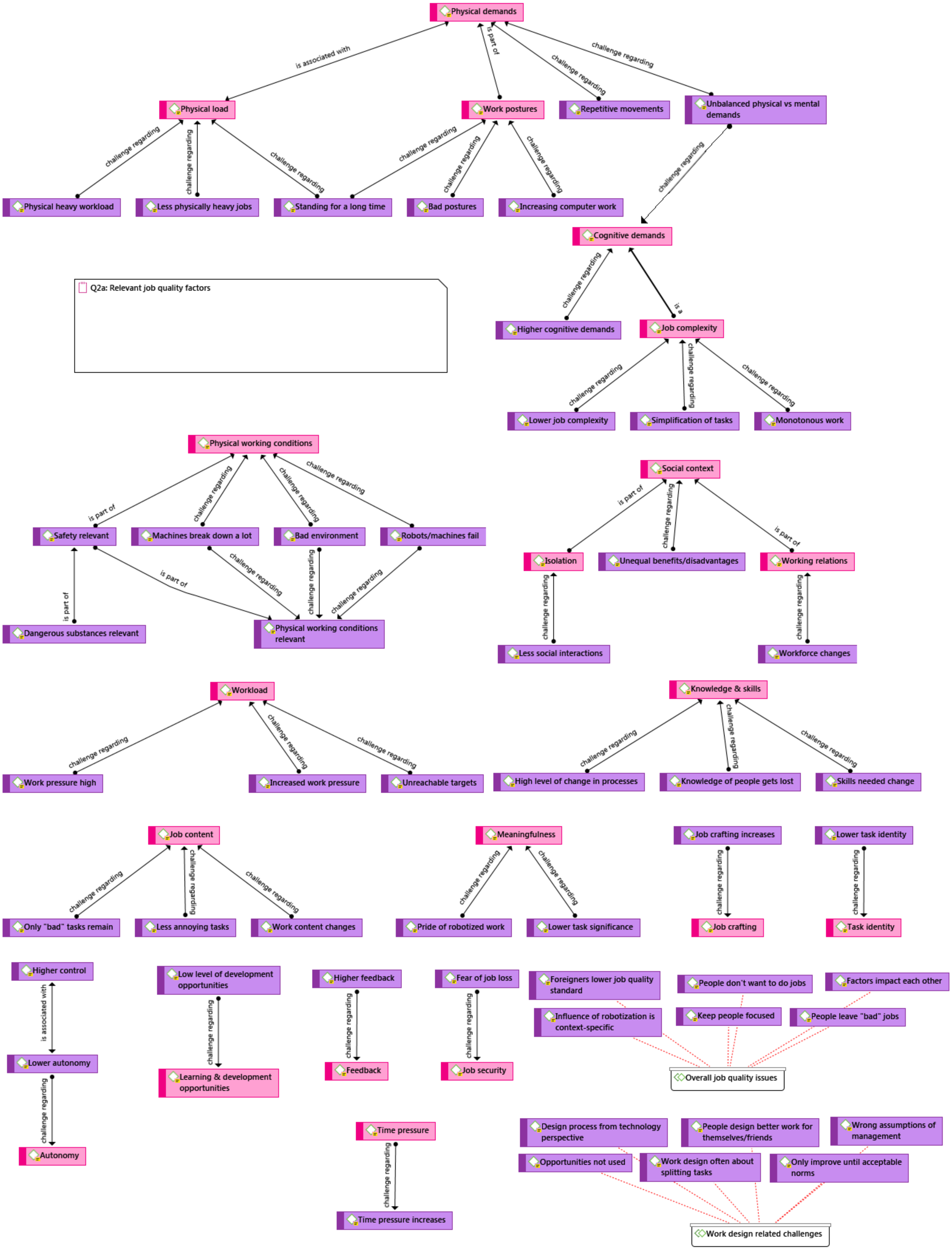


Figure 5.5: Network linking codes of the challenges (purple) to the job quality factors (pink) they are about.

Chapter 6

Conceptual solution framework

This chapter presents the final conceptual solution framework regarding the implementation of job quality in a BPMS. This conceptual solution framework is shown in Figure 6.1. The framework shows eight guidelines related to the five previously selected job quality factors. These guidelines can be implemented in a BPMS and would ensure that the job quality factors described in the framework are supported by this BPMS. Furthermore, the framework describes twelve variables which should be implemented in design-time and run-time regarding the different guidelines.

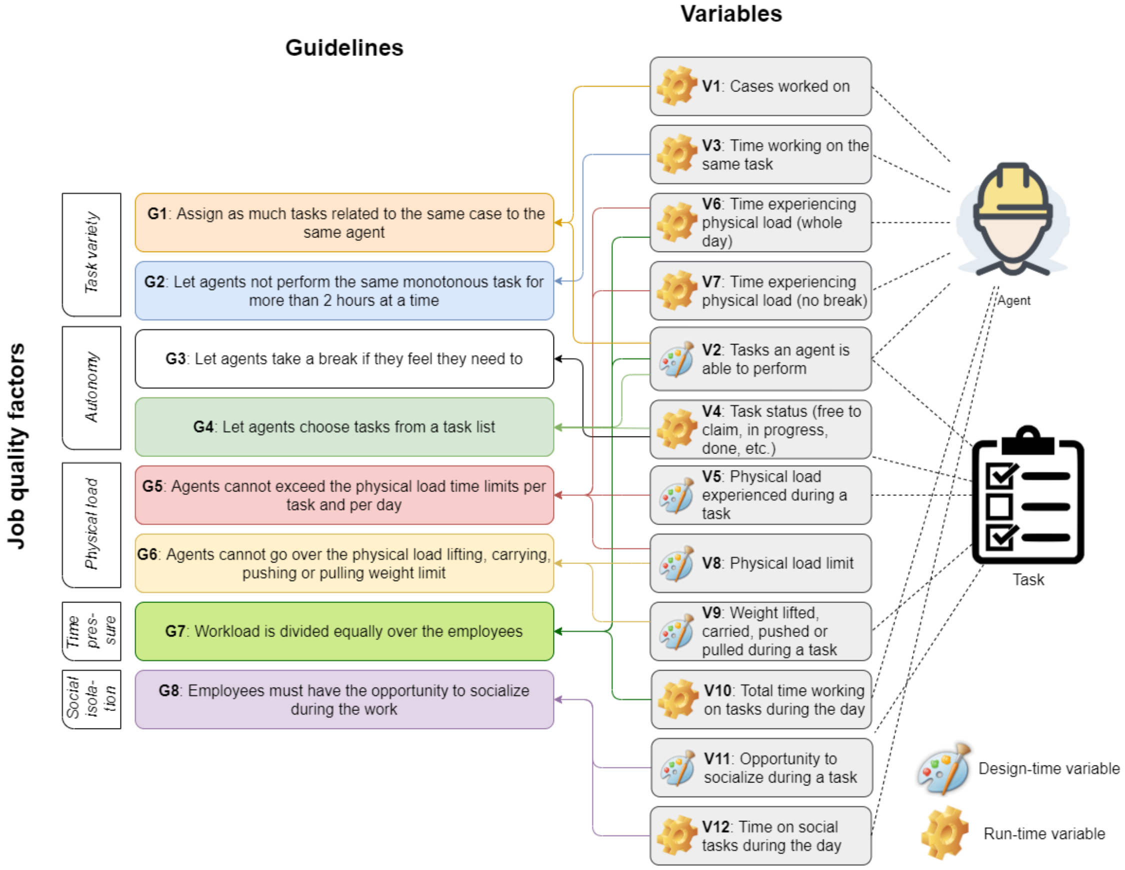


Figure 6.1: Conceptual solution framework (D5) containing the selected job quality factors (D2), the proposed guidelines (D3), the proposed variables (design-time and run-time) (D4), and how all these aspects are related.

The framework works as follows: If a process is analysed and for example social isolation and task variety are found to be a problem regarding job quality within this process, the framework suggests to implement guidelines 1, 2 and 8 in the BPMS. But, in order to successfully support these guidelines, also some variables must be implemented in the BPMS. In this case, the variables needed to implement the guidelines successfully are the variables 1, 2, 3, 11 and 12. Variables 2 and 11 are design-time variables, so the BPMS should store some *static* information regarding these variables. Variables 1, 3 and 12 are run-time variables and therefore, the BPMS needs to *dynamically* update information regarding these variables during the execution of the process.

The framework in Figure 6.1 is the main result of executing the steps of the solution design phase of this research as described in Section 4.2.2 in the Chapter 4. In order to come to this framework, several intermediate results were obtained, which are described in the rest of this chapter. These intermediate results consist of the job quality guidelines (D3) and the related variables (D4), which finally led to the conceptual model in which the job quality factors, guidelines and variables come together (D5) as shown in Figure 6.1. The goal of this conceptual solution framework is to visualize the job quality factors, guidelines, variables and their relations in an easy-to-understand way. This conceptual solution framework is the basis for the implementation, application and evaluation phases of this research.

6.1 Guidelines

This section describes the results collected by executing the research steps as described in Section 4.2.2 in Chapter 4.

Guidelines from literature and other sources The exploratory literature research performed to find useful BPMS solutions regarding the five previously described job quality factors, led to a list of 42 possible solutions, mechanisms or rules. This list is presented in Table G.1 in Appendix G, together with the sources of each solution idea.

Most of the BPMS solutions regarding autonomy were extracted from a report by Vanderfeesten and Reijers regarding increasing work autonomy in workflow management systems (Vanderfeesten & Reijers, 2006). In their research, they propose a number of "tuning measures" to configure a workflow management system (which is highly similar to a BPMS) in such a way that human needs are supported better. Their ideas are based on the previously described job characteristics model and on theory of Workflow Management Systems (WfMS's), and are therefore also highly applicable in this research. More specifically, they propose measures which "provide the performer of the work with more autonomy", making their findings especially useful for the purpose of finding autonomy-related BPMS solutions. An example of one of their measures is SH PULL: "Use a shared worklist, from which an employee can choose himself: pull-manner" (Vanderfeesten & Reijers, 2006).

Another important source for BPMS solution ideas are the workflow resource patterns described by Russell and colleagues (Russell, ter Hofstede, Edmond, & van der Aalst, 2004). These workflow resource patterns "aim to capture the various ways in which resources are represented and utilized in workflows" (Russell et al., 2004). This focus on resources in workflows is highly useful for this research. For example, the first pattern described in their report is Pattern R-DA (Direct Allocation). If a WfMS (or a BPMS) supports this pattern, it means the user of the system has the ability to specify at design time the identity of the resource that will execute a task (Russell et al., 2004). Using these kind of patterns in a BPMS, could possibly improve job quality for resources in workflows.

A pre-selection of this list was made of rules which are potentially suitable to implement, and this pre-selection was later discussed with experts to decide on a final list of guidelines. Whether an idea was selected for the expert discussion, is also shown in Table G.1 in Appendix G.

Guidelines from interviews During the semi-structured interviews, questions 8, 11, 14 and 15 of the questionnaire in B were asked to collect ideas regarding possible BPMS solutions. The answers were transcribed and coded, leading to 19 different solution suggestions. These were linked to the challenges and job quality factors they relate to, and this resulted in the network shown in Figure H.1 in Appendix H. An example from the network is the proposed solution "Train employees". This is a solution for the challenge "Monotonous work" which is related to the job quality factor "Task variety". The idea behind this solution is that if employees are trained to get more skills than just the skills needed for one type of task, they will be able to execute more different tasks. Their overall job will become less monotonous if they execute a bigger variety of tasks. Although a lot of interesting solutions are proposed, most of them are related to design-time solutions in manufacturing processes. These type of solutions are not relevant in this research, since the goal is to create guidelines which can be implemented in a BPMS. A BPMS does not support design-time solutions. A BPMS can for example allocate tasks to different resources in *run-time* to support job quality, but it cannot change the content of a task, which would be a *design-time* solution. The solutions mentioned in the interviews which are potentially useful regarding run-time were also found in the literature research, for example the solutions "Task rotation" or "Letting the employee choose". Therefore, the results of the interviews will not be used to further enhance or change the list of guidelines which was discussed with the experts.

Final guidelines based on expert opinion The rules and mechanisms listed in Table G.1 in Appendix G for which the last column states they are candidates for the model, were used as a start for a discussion with two experts (one ergonomist and one human factors engineer). The goal of the discussion was to find whether a guideline would be useful to implement in BPMS software, and therefore should be part of the solution design. The main results from the discussion per job quality factor are as follows:

- **Physical load:**
  - Extra resource for the 25 kg lifting/carrying limit is a good idea.
  - The physical load time limits are a good idea, but during implementation, decide how you are going to enforce them. Suggestion is to implement warnings and make sure no one can possibly go over the limit.
- **Isolation:**
  - No good solution in the list, so think of something ourselves. You can do something similar as for physical load, so decide whether a task is solitary or not, and limit the total time a worker can perform solitary tasks.
- **Task variety:**
  - This job quality factor is very important, also regarding physical load.
  - They mostly like the idea of case assignment, which is related to history-based allocation, it automatically leads to a higher task variety, and is also advised by TNO.
  - They advise to try and make the cycle time per task as high as possible, this means there is more task variety within the task.
  - If case assignment and/or a high cycle time is not possible , the advice is to rotate tasks every 2 hours to prevent work becoming too monotonous.
- **Autonomy:**
  - They really like the idea to let a worker pause if they feel the need to, could also be good for physical load.
  - They also like the idea of letting workers choose (pull) tasks themselves from a work list.
  - Choosing the appearance of work items on the task list (FIFO, random, etc) could be nice, but has a lower priority.
- **Time pressure:**
  - Don't really see the point of not showing work items yet.
  - Time pressure is dependent on many things, and most of these cannot be altered by BPMS.

– Based on the deferred allocation pattern, the best and only option seems to divide workload during the day as equally over employees as possible, to avoid that one employee for example is experiencing a high time pressure, while others are not working enough.

Based on this discussion and the previous findings, the final guidelines (D3) were defined. These are shown in Table 6.1, together with the theory they are based on. Some guidelines are also supported by statements during the interviews, which is also shown in Table 6.1.

Table 6.1: Proposed guidelines regarding the selected job quality factors (D3)

JQ factor	**Guideline**	**Source(s)/theory**
Task variety	**G1:** Assign as much tasks related to the same case to the same agent.	Case-based assignment (Russell et al., 2004), case handling (Vanderfeesten & Reijers, 2006), specialist-generalist (Russell et al., 2004).
	G2: Let agents not perform the same monotonous task for more than 2 hours at a time.	Task rotation, TNO oplossingsrichtingen (TNO, 2018), Interviews 1, 2, 5 and 6
Autonomy	**G3:** Let agents take a break if they feel they need to	Suspension/resumption (Russell et al., 2004)
	G4: Let agents choose tasks from a task list	Selection autonomy (Russell et al., 2004), pull-mechanism (Vanderfeesten & Reijers, 2006), Interview 1
Physical load	**G5:** Agents cannot exceed the physical load time limits per task and per day.	See Table 6.2
	G6: Agents cannot exceed the physical load lifting/carrying/pushing/pulling limit.	Max 25 kg (NRK, 2010b), Extra resources (Russell et al., 2004), Interview 4
Time pressure	**G7:** Workload is divided equally over the employees	History-based allocation (Russell et al., 2004)
Social isolation	**G8:** Employees must have the opportunity to socialize during the work.	-

Since there are multiple time limits taken into account regarding physical load, one general guideline was proposed (G5) including multiple physical load limits. The limits taken into account in this research are shown in Table 6.2.

Table 6.2: Physical load limits related to G5

Physical load limit	**Source(s)**
Maximum 6 hours computer work per day	(InPreventie, 2020a)
Maximum 2 hours unfavorable posture per day	(5xbeter, 2020)
Maximum 4 hours standing per day	(de Korte, Könemann, & Bosch, 2016) & Interview 4
Maximum 1.5 hours the same physical load at a time	(TNO, 2018), interviews 1, 2, 5 and 6
Maximum 2 hours computer work at a time	(InPreventie, 2020a), interviews 1, 2, 5 and 6
Maximum 1 hours standing at a time	(de Korte et al., 2016)

6.2 Variables

To find the variables which should be implemented to support the monitoring of the selected job quality factors (D4), the steps as described in Chapter 4 were executed, leading to the results described below. The variables describe parameters or data which should be entered, saved and/or updated in the BPMS in order to successfully implement the proposed guidelines of D3.

Variables from interviews To collect some first ideas regarding the variables which would be useful to implement in a BPMS, during the interviews question 13 of the questionnaire in Appendix B was asked. The results regarding this question were coded, and these variable codes were linked to the job quality factors and if applicable, the possible solutions mentioned during the interviews. The result of this is shown in the network in 6.2. An example in the network is the variable "Type of tasks" related to the job quality factor "Task variety" and the solution "Switch tasks". This means an interviewee suggested to, for example, save the type of tasks someone has performed in a database, in order to let agents switch tasks to increase their task variety.

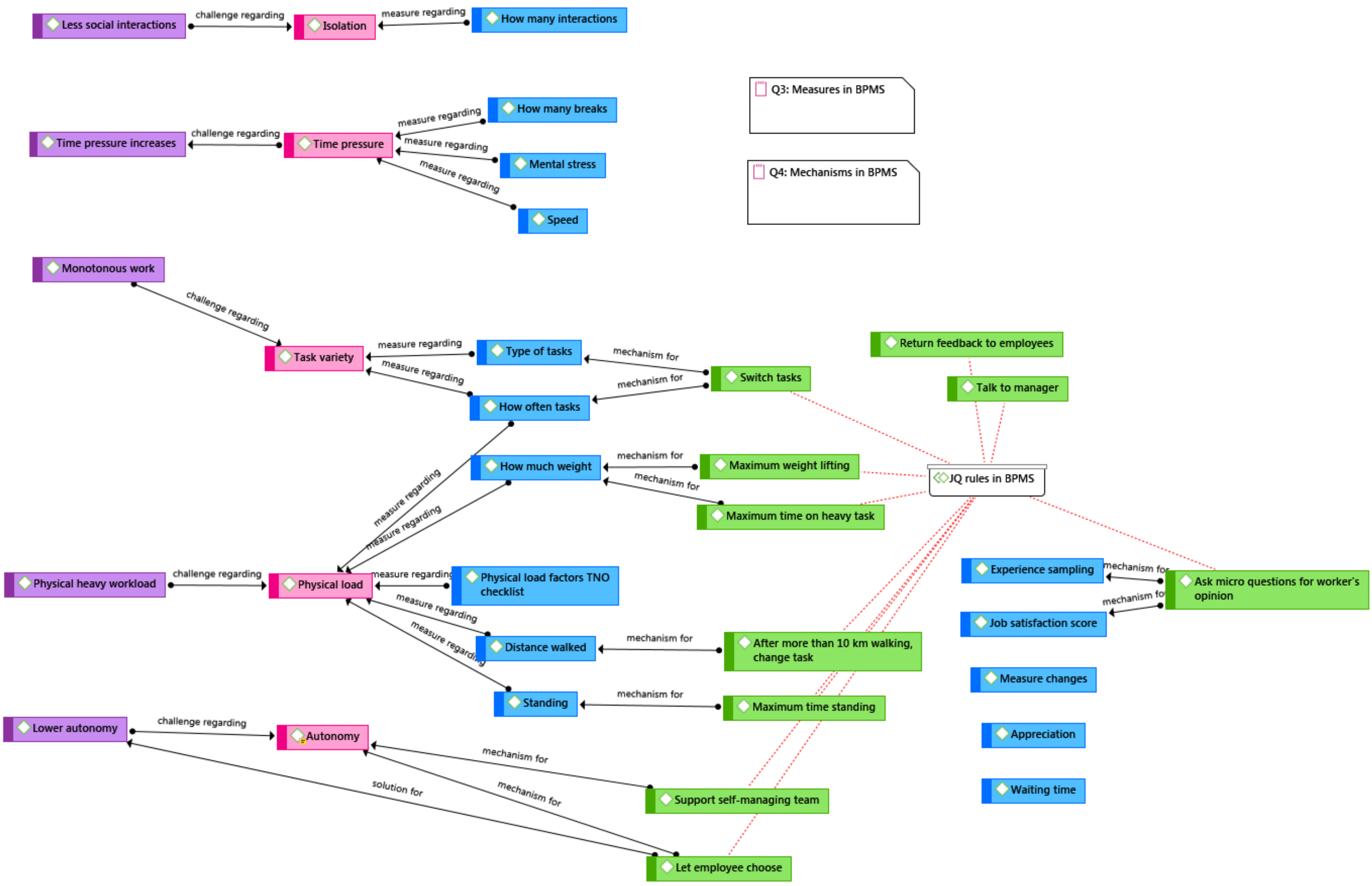


Figure 6.2: Network showing the codes regarding BPMS variable ideas posed during the interviews, and their relation to the job quality factors and suggested solutions

Final variables Based on the collection of ideas during the interviews, and the guidelines as defined after the expert discussion, the final list of variables which should be implemented (D4) was created. While doing this, it became clear that almost all variables represent characteristics regarding two categories: the tasks in the process, and the agents performing the tasks. Also, some variables represent static information, which is defined during design-time, and which does generally not change during the process execution. Other variables represent dynamic information, which is updated constantly in run-time during the execution of the process. The final variables, the related category, whether they are design-time or run-time and the relation to the guidelines of D3, are listed in Table 6.3. If the variable was suggested during one or more of the interviews, this is also stated.

Table 6.3: Variables which need to be implemented to support the guidelines (D4).

Variable	**Related instance(s)**	**Design- or run-time**	**Related guideline(s)**	**Interview support?**
V1: Cases worked on	Agent	Run-time	G1	No
V2: Tasks an agent is able to perform	Agent and/or task	Design-time	G1, G4, G7	No
V3: Time working on the same task	Agent	Run-time	G2	Yes
V4: Task status (free to claim, in progress, done, etc)	Task	Run-time	G3, G4	No
V5: Physical load experienced during a task	Task	Design-time	G5	Yes
V6: Time experiencing physical load (whole day)	Agent	Run-time	G5, G7	Yes
V7: Time experiencing physical load without a break or different kind of load in between	Agent	Run-time	G5	Yes
V8: Physical load limit	-	Design-time	G5, G6	Yes
V9: Weight lifted, carried, pushed or pulled during a task	Task	Design-time	G6	Yes
V10: Total time working on tasks during the day	Agent	Run-time	G7	No
V11: Opportunity to socialize during a task	Task	Design-time	G8	No
V12: Time on social tasks during the day	Agent	Run-time	G8	Yes

Chapter 7

Use case application and implementation

In order to implement the conceptual solution framework described in the previous chapter, two use cases were selected to apply the framework to. The results of the application and implementation are described in this chapter. The results of the evaluation of this application in terms of feasibility and usefulness are presented in Chapter 8.

For each use case, the relevant guidelines of the framework were selected and implemented in BPM software. This selection is shown in Figure 7.1. For use case 1, guideline 5 and 6 related to physical load were selected, and for use case 2, guideline 2, 3 and 4 related to task variety and autonomy were selected. In this chapter the use cases, the selection of the guidelines and the way these guidelines were implemented (D6) are discussed in more detail. The executed steps are also described in Section 4.2.3 of Chapter 4.

7.1 Use cases & guideline selection

In this section, the two use cases and the related guidelines of the conceptual solution framework are described.

7.1.1 Use case 1: Manual loading at Thomas Regout International (TRI)

Use case description Thomas Regout International (TRI) is a company which provides and produces telescopic sliding solutions. Their factory is located in Maastricht in the Netherlands. They have participated as a pilot in the HORSE project. During this pilot, they tried to find a robotic solution for the process of manually loading (and unloading) profiles onto (or from) a rack. In this process, the (heavy) profiles have to be lifted from a bin, and hung onto a rack one by one by a worker. Unfortunately, until now, no affordable solution has been found. The process regarding the manual loading will serve as a use case in this project. The BPMN process model is shown in Figure 7.2. This process model is based on the results of the process analysis for the HORSE project.

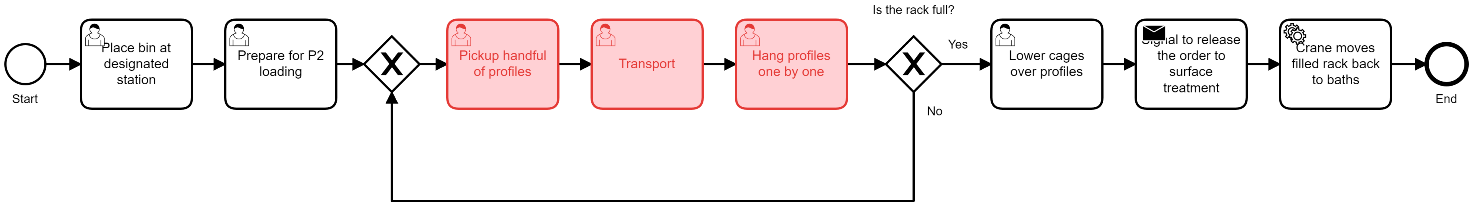


Figure 7.2: Process model of the manual loading process at TRI. Red tasks are tasks with physical load risks for employees.

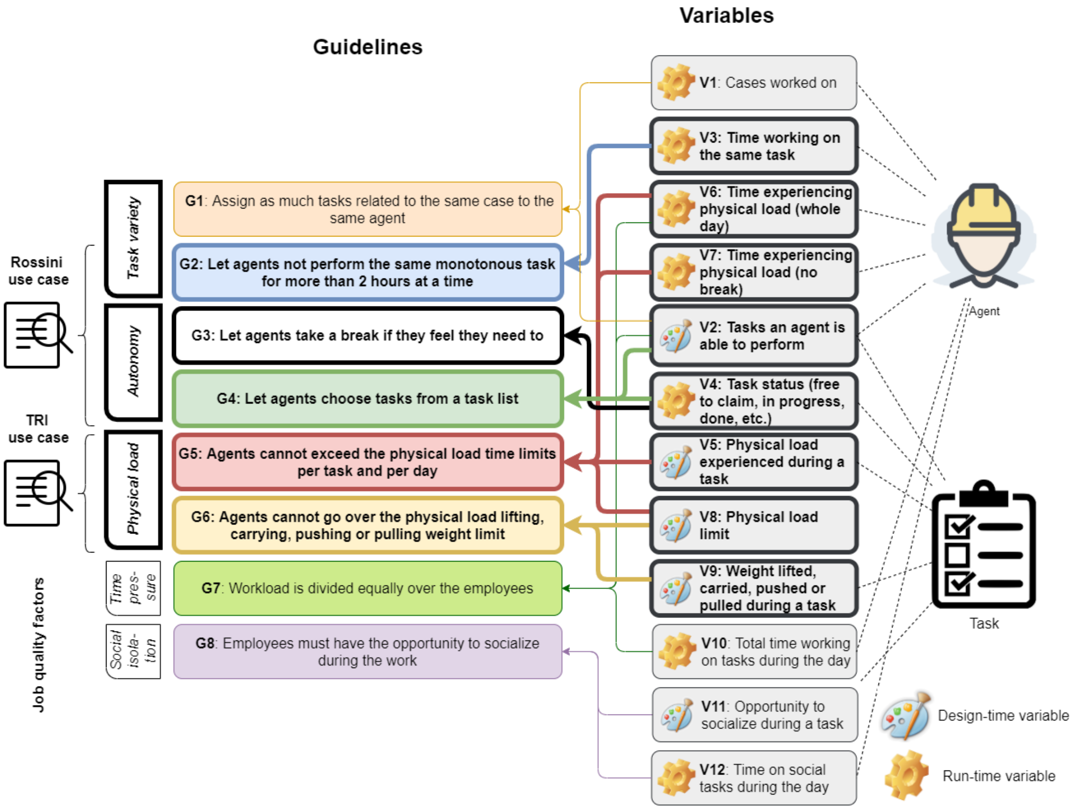


Figure 7.1: Selected guidelines and variables for the implementation and evaluation, based on the TRI and Rossini use case.

Guideline selection When looking at the process from a job quality perspective, the biggest challenge in the manual loading process is related to physical load. Three tasks within the process have physical load risks according to the analysis of Polderdijk (Polderdijk, 2017). These are shown in red in Figure 7.2. When looking at the conceptual model in Figure 6.1, two guidelines are related to the job quality factor physical load. Also, some design-time and run-time variables are related to these guidelines and should therefore be taken into account. In conclusion, guidelines G5 and G6 will be implemented, as well as the related variables V5, V6, V7, V8 and V9. These are highlighted in Figure 7.1, together with the selected guidelines and variables regarding the second use case, which is discussed now.

7.1.2 Use case 2: Packaging process at one of the Rossini pilots

Use case description One of the pilot companies of the Rossini project has a process in which products are packaged by machines. The goal is to implement automation and robotic solutions in this packaging process, where currently a human worker is responsible for the loading, unloading and repairing of the packaging machines. No BPMN process model existed yet for this process, so the process model as shown in Figure 7.3 is based on the use case description of the pilot for the Rossini project.

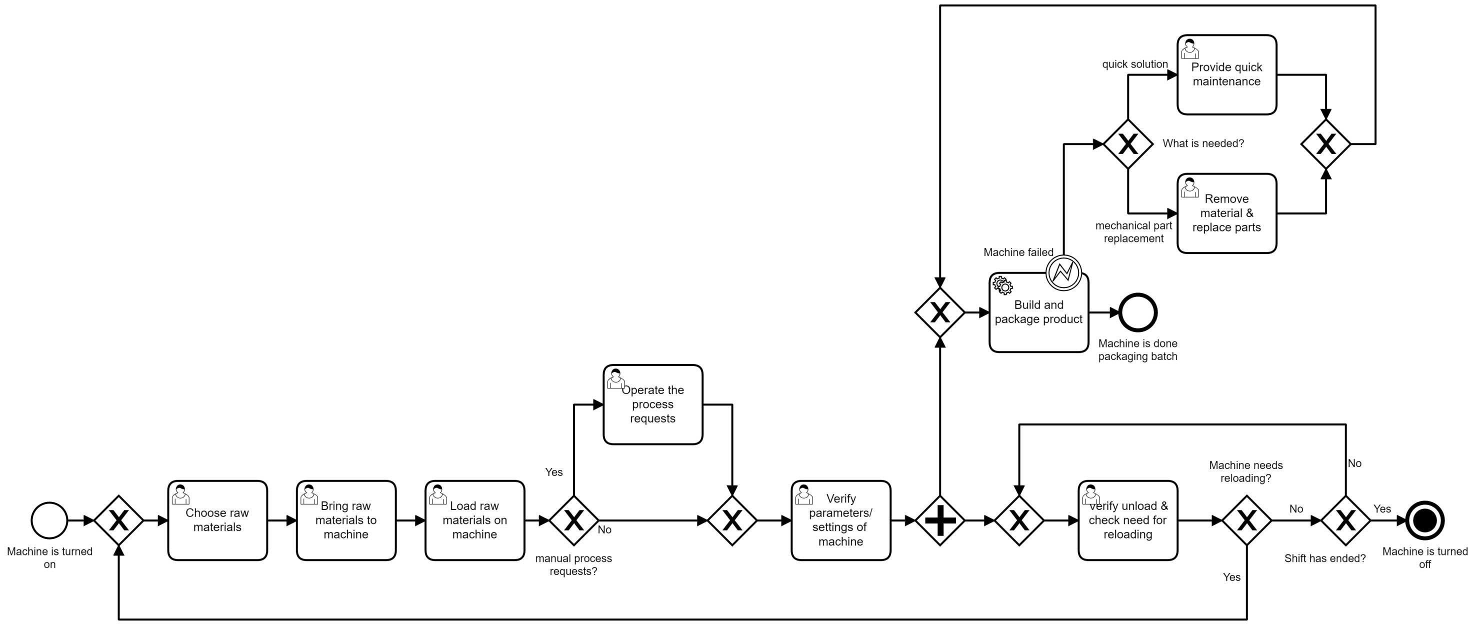


Figure 7.3: Process model of the packaging process at the Rossini pilot company.

Guideline selection Currently, the process is performed for five machines simultaneously by one worker, so one worker is loading, unloading and fixing five machines at the same time. When selecting relevant job quality factors in this case, the first one that came to mind when looking at the conceptual model in Figure 6.1 is social isolation, since the worker is working alone. However, in the scope of this research, where the goal is to apply solutions within one process, this guideline cannot be implemented. A solution for example would be to rotate workers who are assigned to this process during the day, so they get the chance to also work in more social environments and processes. But, since the scope of possible solutions lies within the packaging process, this does not hold. The same holds for the time pressure factor: if all machines break down at the same time, time pressure would be a very relevant factor to consider. But the same problem occurs as the social isolation factor: a higher-level scope is needed to equally divide the workload as proposed by guideline 7, since workload cannot be divided differently among one worker. When looking at the proposed solution by the Rossini project, where a big part of the work is taken over by robots, task variety comes to mind. However, to implement guideline 1, more workers should be working on the process, in order to rotate tasks among them. Guideline 2 however, is suitable in this case because it can force the worker to take a break or first undertake other tasks instead of the same type of task for a long time. Autonomy is also a relevant factor to consider: since there is only one worker, it could be a good practice to increase this workers autonomy, which may also increase his or her task variety and/or decrease the time pressure. To elaborate on this, when again thinking of the possibility that all machines break down at the same time, it would be good to let this agent take a break when feeling the need to, or let the agent perform a different task in between, to make sure the agent is not forced to rushing and fixing all machines in a row and in this way making his work very monotonous and stressful due to time pressure. To summarize, the chosen guidelines to implement in this case are G2, G3 and G4, which are related to the variables V2, V3 and V4. These are also highlighted in Figure 7.1, together with the selected guidelines and variables related to the TRI use case.

7.2 Functionalities

For each guideline selected based on the use cases, functionalities were described which should be implemented in the Camunda software, and be evaluated afterwards. These functionalities are described in Table 7.1.

Table 7.1: Guideline functionalities to implement in Camunda

Task variety	
G2: Let agents not perform the same monotonous task for more than 2 hours at a time.	
F2.1	When an agent is at X percent of the same task time limit of 2 hours, he or she receives a warning.
F2.2	When an agent reaches the 2 hours same task limit while still working on the task, he or she is forced to stop working on the task.
F2.3	When an agent has reached the 2 hours same task time limit, he or she has to take a 10 minute break or perform another task before he or she is able to start working on the same task again.
F2.4	When an agent is at X percent of the same task time limit of 2 hours, but has not yet reached it, he or she can not choose the same task from his or her task list, until he or she has performed another kind of task or taken a break.
Autonomy	
G3: Let agents take a break if they feel they need to.	
F3.1	While an agent is working on a task, he or she can pause the task and continue working on it after taking a break.
F3.2	If an agent has paused working on a task, the task in progress cannot be claimed and finished by another agent.
F3.3	After finishing a task, an agent can choose to first take a break before continuing to work on another task.
G4: Let agents choose tasks from a tasklist	
F4.1	Tasks are put on the candidate task list of an agent from which the agent can select and pull the task of his or her choice to work on.
F4.2	Tasks are not pushed to an agent by the system.
Physical load	
G5: Agents cannot go over the physical load time limits per task and per day	
F5.1	When an agent has reached the per day time limit of a type of physical load, this agent cannot start or execute tasks including this kind of physical load anymore on this day.
F5.2	When an agent is at X percent of the physical load time limit of a type of physical load, he or she can still execute, but not start tasks including this type of physical load.
F5.3	When an agent is at X percent of the physical load time limit of a type of physical load, he or she receives a warning.
F5.4	When an agent reaches the physical load time per day limit of a kind of physical load he or she is currently experiencing during the execution of the current task, he or she is forced to stop working on the task.
F5.5	When an agent reaches the physical load time per task limit of a kind of physical load he or she is currently experiencing during the execution of the current task, he or she is forced to stop working on the task and take a break or perform another task for an X amount of time before the current type of physical load task becomes available again.
F5.6	When an agent starts working on a new day, all physical load timers are reset and the agent can execute all types of tasks.
G6: Agents cannot go over the physical load lifting, carrying, pushing or pulling weight limit	
F6.1	When an agent claims a task of which the lifting, carrying, pushing or pulling weight is too high for one agent, a free agent who is authorized and capable of performing this type of task is automatically assigned to help this agent.
F6.2	When an agent claims a task of which the lifting, carrying, pushing or pulling weight is too high for one agent and there is no authorized and capable free agent to help with the task, the agent cannot claim and start working on the task.

7.3 Camunda implementation

In this section the implementation of the selected variables and guidelines in the Camunda software is explained in more detail. An overview of the software, interfaces and modules used to build the demo is shown in Figure 7.4. Firstly, a quick description of the Camunda software and its relevant functions is presented, and secondly, the implementation of the variables and guidelines into the different components of Figure 7.4 is discussed.

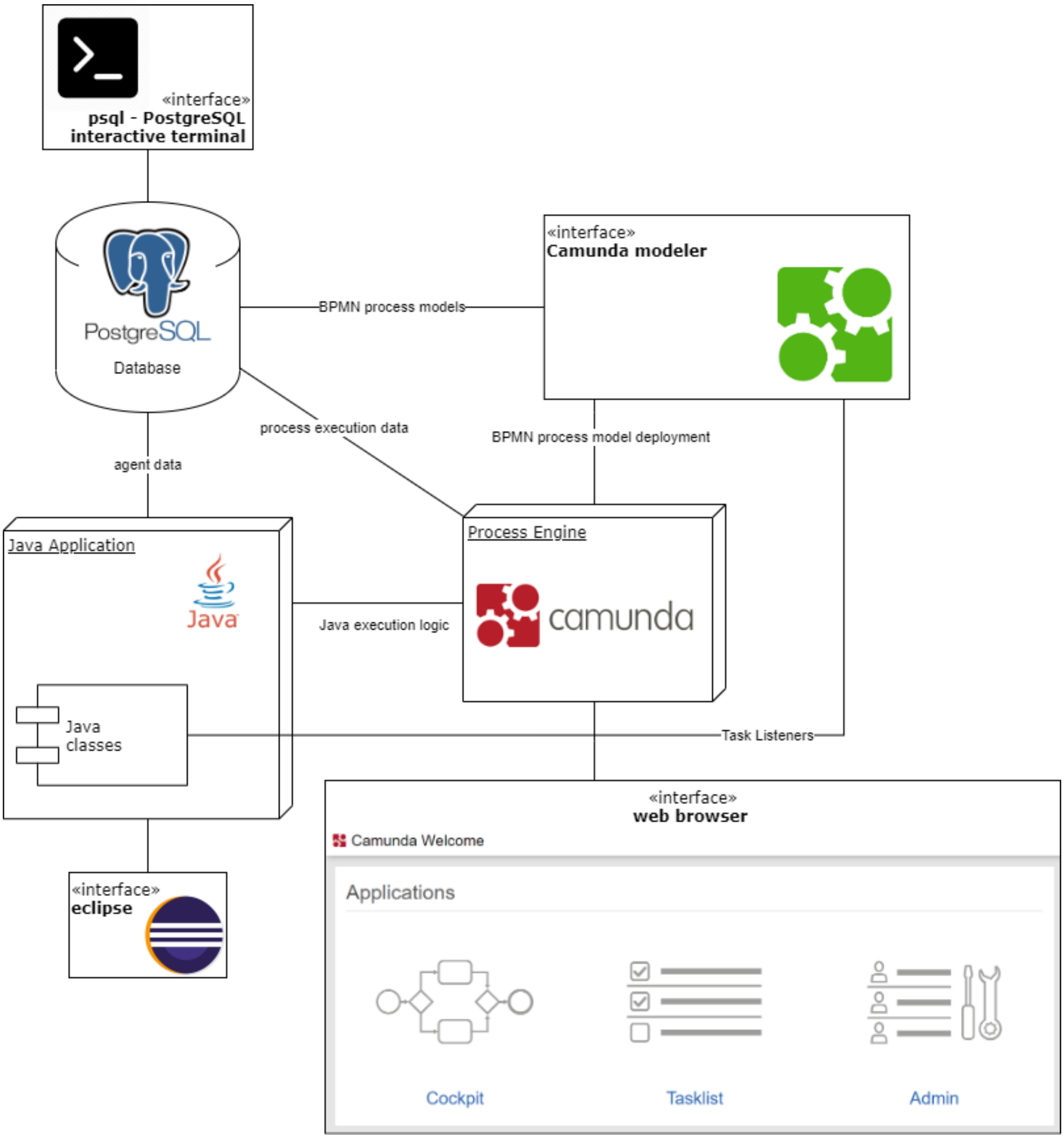


Figure 7.4: Architecture diagram of the different components of the demo.

7.3.1 The Camunda software

Before explaining how the guidelines were implemented in Camunda, it is important to get a basic understanding of how Camunda works. Camunda is a task allocation software, including a process engine for workflow automation, of which the following modules are most important regarding this implementation:

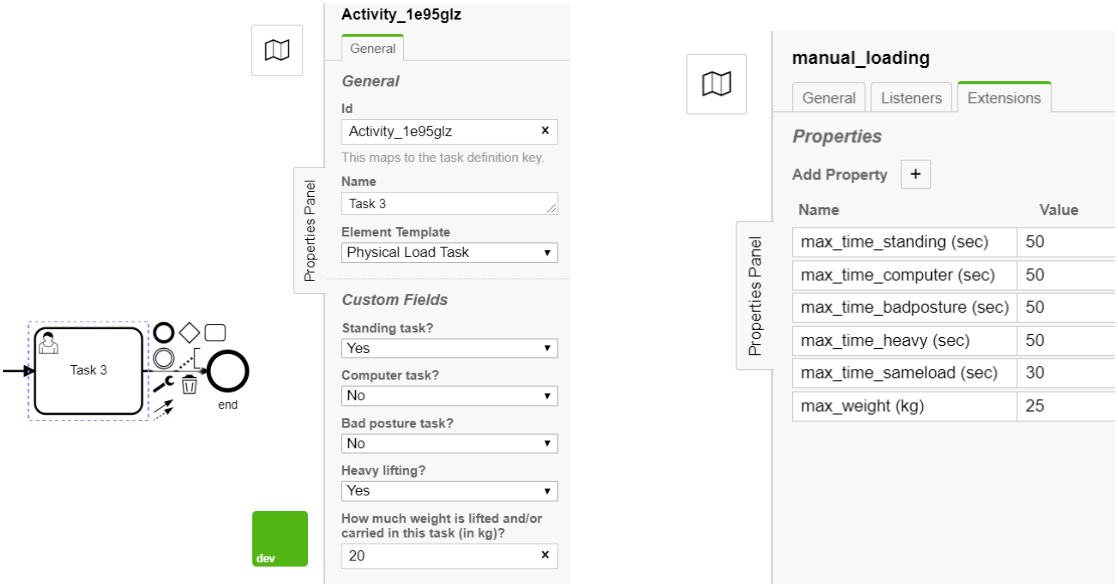
- Camunda modeler
- Camunda tasklist
- run-time and historic database (in this case PostgreSQL)
- Java classes

The **Camunda modeler** is a tool in which you can create executable BPMN process models. It supports the basic BPMN elements like activities, gateways and events. For each activity, the modeler can decide if it is a user task, service task, or one of the many other options. After modeling a process in this modeler, you can deploy the process to the Camunda engine. This is where the **Camunda task list** comes in. This task list can be accessed easily through the web browser. When going to the web page, you can log into Camunda, and in your personal account you can access the task list. The Camunda engine constantly deletes and creates new tasks, based on the previously deployed process model. This is how it works: when a process is started, for example an order comes in, the Camunda engine searches in the deployed process model which activity is happening first regarding this order. In case this is an automatic or service activity, the logic behind it is executed. This is not important for now. If the activity is a user task, it will appear in the task list of the Camunda users. A user who is logged in can see the task, claim it, and complete it. After this is done, the Camunda engine gets a signal the task is completed, after which it will be deleted, and the deployed process model is consulted again. The engine finds the activity or activities followed by this completed task, and will create and send these new tasks to the task list. This continues until the last activity in the process is completed, and the order is finished. During the execution of processes, a lot of data is automatically saved in a database. In this case, the Camunda engine is linked to a **PostgreSQL database**. In this database, both historic data and run-time data is saved regarding the processes, tasks, variables and other instances. The last important module of Camunda is the connection to Java classes. In the process models in the Camunda modeler, you can link **Java Task Listener classes** containing Java code to specific events of the activities. For example, when linking a Java class to the "complete" event of an activity, the code in this class will be executed whenever a user completes this kind of task. Within this Java code it is also possible to access the historic and run-time data of the engine through a Java API. In this way, the data in the database can be used for example to assign specific tasks to specific users, which is highly useful for the purpose of this project.

7.3.2 Implementation of the guidelines and variables

In order to implement the previously selected guidelines and variables, the modules as described in the previous sections were used or extended. How this is done is described in this section. The implementation is also described in a similar way in the screencast in the following link: `https://youtu.be/xI6__woCFWo`.

Design-time variables in Camunda modeler The design-time variables V2, V5, V8 and V9 as shown in Figure 7.1 were implemented in the Camunda modeler. Firstly, regarding V2, no extension was needed. In the Camunda modeler, it is already possible to choose which users or user groups are allowed to perform a specific user task. In turn, an administrator can choose in his or her Camunda account which users belong to which user groups. This function is enough to specify which tasks an agent is able to perform. In order to implement V5 and V9, the Camunda modeler was extended. When modelling a user task, it is possible to provide specific input regarding this task in the properties panel of the Camunda modeler. To model the types of physical load experienced during a task (V5) and the weight lifted or carried during a task (V9), an element template was created for user tasks, called "Physical load task". This is shown in Figure 7.5(a). This is how it works: when the process modeler (for example a manager) creates a user task in the Camunda modeler, he or she can select the option "Physical load task" in the element template drop down menu in the properties panel. After selecting this, some questions appear regarding the task. When the modeler fills in this small questionnaire, the physical load information is saved to the BPMN activity element, and after deploying the process model, also saved as a variable in the database.



Activity_1e95glz

General

General

Id: Activity_1e95glz

This maps to the task definition key.

Name: Task 3

Element Template: Physical Load Task

Custom Fields

Standing task? Yes

Computer task? No

Bad posture task? No

Heavy lifting? Yes

How much weight is lifted and/or carried in this task (in kg)? 20

manual_loading

Properties

Name	Value
max_time_standing (sec)	50
max_time_computer (sec)	50
max_time_badposture (sec)	50
max_time_heavy (sec)	50
max_time_sameload (sec)	30
max_weight (kg)	25

(a) The V5 and V9 extension

(b) The V8 extension

Figure 7.5: The Camunda modeler extensions regarding the design-time variables

The variables shown in this questionnaire are based on the limits as described by Table 6.2. The variables are automatically saved during the execution of tasks in the data table act_ru_variable of the PostgreSQL database. If a task instance was completed, the variables are deleted from the act_ru_variable table, and saved in the act_hi_varinstance. Both these tables are shown in Figure 7.6 as well. In these tables, one data object containing values for all attributes listed in the table represents one variable. This is how it works: when during the process execution a task instance is created based on the previously described BPMN activity element with the element template 'Phsyical Load Task', then also five instances of the table 'act_ru_variable' are created. For four of these instances the value for the attribute 'type_' is 'boolean' and the values for the attribute 'name_' are 'standing', 'computer', 'heavy', and 'badposture'. The last variable instance created for this table has the value 'weight' for the attribute 'name_' and the value 'string' for the attribute 'type_'. In this way the information is saved to the specific task instances and can be used to assign tasks to the right agents.

Lastly, V8 is also implemented in the Camunda modeler. When selecting the whole process, the modeler can go to the extensions tab in the properties panel. This is shown in Figure 7.5(b). Here, the limits are shown for each kind of physical load. If necessary, the modeler can change these limits. For the purpose of this research, the limits related to time are set in seconds. After deploying the process model, the limits are saved in the PostgreSQL database in the table "phys_limits", as shown in the data model in Figure 7.6.

Run-time variables in PostgreSQL database In order to implement run-time variable V4, no extension in Camunda was needed. The status of a task can be derived from data already stored in the PostgreSQL database. For example, for each task instance, an 'assignee' is stored. When this attribute contains a value, someone has claimed the task and is working on it, so the task status is 'in progress'. When this attribute is empty, no one has started working on the task yet. In order to implement the run-time variables V3, V6 and V7, the PostgreSQL database was extended by an extra table called "agent". In this table, information regarding each agent working in the process is stored and constantly updated while this agent is claiming and completing tasks. When starting up the Camunda engine, each user registered in Camunda in the table act_id_user is copied as an agent to the agent table in the database. For this agent, all attributes shown in the agent table in the data model in Figure 7.6 are stored. The attribute "time_sametask" refers to V3, the attribute "time_sameload" refers to V7 and the attributes "time_standing", "time_computer", "time_badposture", and "time_heavy" refer to V6. The other attributes in the agent table are stored in order to retrieve or update agent information during the execution of the process.

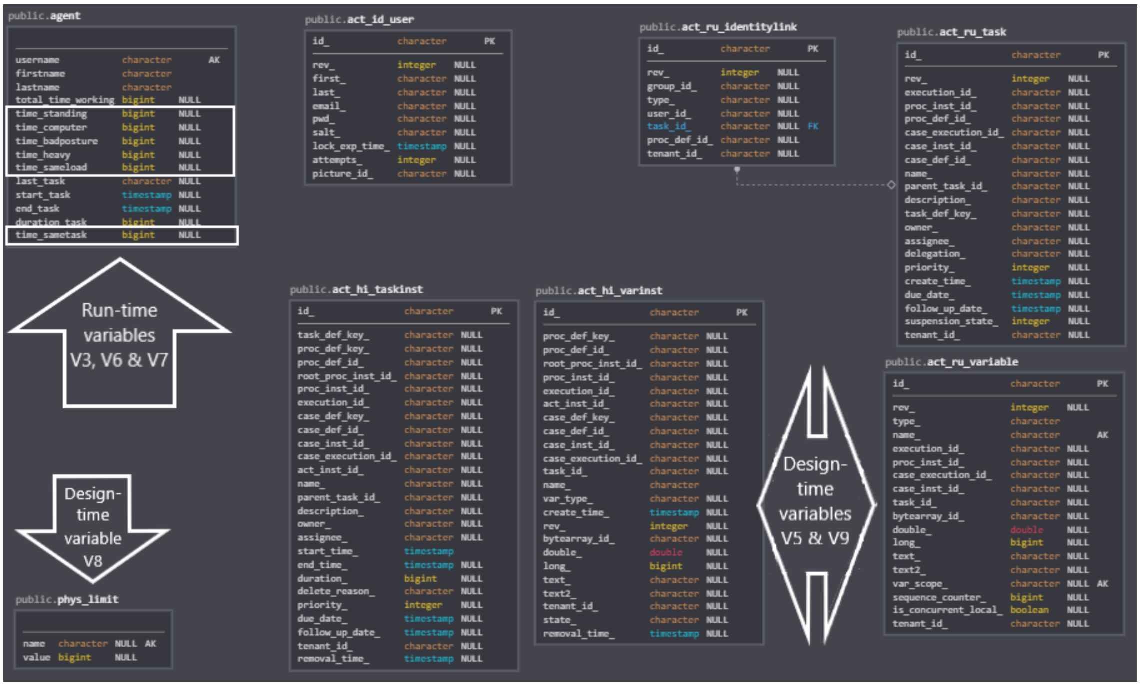


Figure 7.6: Most important data tables in the PostgreSQL Camunda database regarding.

Guidelines in Java Tasklisteners In order to implement the guidelines, the Camunda engine constantly has to update the agent data and respond with a certain logic to actions in the Camunda tasklist. This is done by creating different Java Task Listener classes and linking these to specific task events. In the Camunda modeler, for each user task, the modeler can link a task listener to the events "create", "assignment", "complete" or "delete". A simple example would be that I want to assign Harry to every instance of "Task 1". When I link the tasklistener "Task1Listener.java" to the create event of "task 1", and inside this java Tasklistener I write code which sets "Harry" as the assignee of the task, this will happen every time a new instance of this task is created. The Java Tasklisteners which were created for this implementation, which guidelines they support and the main functions they have are described below.

TaskAssignmentHandler.java

This Java class takes care of making sure that no worker exceeds the physical load limits. It is linked to the "create", "assignment" and "complete" events of all user tasks of the processes regarding the use cases, and supports the logic of G2, G5 and G6. This is what happens for each event type:

- **Create** event
    1. Check whether the task is a physical load task, and if yes, which types of physical load are experienced during the task (V5).
    2. Find which of the currently working agents are still within the relevant physical load limits per day (G5, V6 & V8).
    3. Check if these agents have performed this type of task previous to this one, and if so, if they are within the same task limit (G2 & V3).
    4. Check if these agents have performed this type of physical load in their previous task, and if so, if they are within the same load limit (G5, V7 & V8)

5. The created task is put in the task list of the agents who are within all previously mentioned limits, under the tab 'candidate tasks', from which they can claim and start working on the task.

- **Assignment** (or claim) event
  1. Check whether the task exceeds the carrying/lifting/pushing/pulling limit, and if so, assign an extra agent to help execute the task (G6 & V9).
     (a) If no agent is available to help, a message appears that the agent cannot claim the task at this time and the task remains under the tab 'candidate tasks' in the task list.
  2. Set the start time of the execution of this task in the database.
  3. Check which agent has claimed the task, how much time he or she can still work until the relevant limits are reached, and start timers for these limits.
  4. If the agent does not complete the task in time to stay within the limits, the following things happen:
     (a) When the agent reaches 80% or 90% of a limit, a warning is sent that the agent is approaching the specific limit (F2.1 & F5.3)
     (b) When the agent reaches the limit, the task is 'unclaimed' from this agent and he or she has to stop working on it (F2.2 & F5.4). The task reappears in the 'candidate tasks' tab of the task list of specific agents based on the logic described under the 'create' event . Now, two more things happen based on the type of limit reached:
        i. If the limit was a 'whole day' limit, the agents candidate task list is updated to only show tasks without this kind of physical load.
        ii. If the limit is a 'same task' or 'same load' limit, the current task of the agent is switched to a break, during which the agent cannot claim tasks of this type or load. When the break is done:
           A. The agents same task and/or same load time are set to zero in the database.
           B. The candidate task list of the agent is updated, so the task he or she was working on before the break, reappears in his or her candidate task list.

- **Complete** event
  1. Check whether the completed task exceeds the carrying/lifting/pushing/pulling limit and if so, also complete the 'help' task of the extra assigned resource.
  2. Set the end time and duration of the executed task in the database.

UpdateTimeWorking.java

This Tasklistener is linked to the "end" event of each task in order to update the working times of an agent in the database, after he or she completed a task.

- **End** event
  1. Check whether the task is a physical load task, and if yes, which types of physical load are experienced during the task (V5).
  2. Retrieve the duration of the task from the database.
  3. Update the agent's total working time and the total times the agent has spent today (or without a break) on the specific type(s) of physical load (V6 & V7) or specific task type (V3).
  4. Update the candidate task list of the agent.
  5. Set the id of the task which just ended in the database in the agent attribute 'last_task'.

BreakListener.java

This Tasklistener is attached to the create, assignment and complete events of the "Take Break" activity in the Rossini use case, and supports the logic of G3. This activity does not exist in the original (descriptive) process model presented in Figure 7.3, but was added to the (executable) process model presented in Figure 8.4 in Chapter 8 to succesfully implement G3. This activity was introduced in the BPMN process model to represent a pause button for workers in the form of a task in their task list, which they can use to take a break during the execution of tasks in the process. When they claim this 'Take Break' task, their break starts, and when they complete it, the break ends.

- **Create** event
    1. Put the 'Take break' task in the candidate task list of all users.
- **Assignment** (or claim) event
    1. Check whether the agent is currently working on a task
        (a) If so, make sure this task does not appear in anyone's candidate task list (V4).
- **Complete** event
    1. Check if the agent was working on a task before taking the break (V4).
        (a) If so, re-assign the task to this agent, so he or she can continue working on it.
    2. Update the agent's candidate task list.

MyDatabaseHandler.java

This Java class is not a Tasklistener, but was created to store methods which are useful to interact with the PostgreSQL database. It contains for example, the method selectAgent(String username), which is used to retrieve an agent object from the PostgreSQL database and use it in the Java code.

Chapter 8

Use case evaluation

This chapter describes the results of the feasibility and usefulness evaluation of the application of the conceptual solution framework to the two use cases described in Chapter 7. For each use case, the relevant guidelines of the framework as highlighted in Figure 7.1 were implemented. Then, for each use case, an evaluation was executed as described in Section 4.2.3 of Chapter 4. For the TRI use case, the feasibility and usefulness of implementing G5 and G6 of the conceptual solution framework were evaluated. For the Rossini use case, the feasibility and usefulness of implementing G2, G3 and G4 were evaluated. The results regarding *feasibility* were positive for both use cases; the implementation of all selected guidelines in the BPMS Camunda was successful, which means implementing these kind of guidelines in a BPMS is indeed possible. The results regarding *usability* were varying; implementing guidelines 5 and 6 was evaluated as useful, but the usefulness of implementing guidelines 2, 3 and 4 was evaluated as doubtful, maybe even as harmful regarding the related job quality factors.

In the rest of this chapter, the more detailed results of the feasibility (D7a) and usefulness (D7b) evaluation are described.

8.1 Feasibility evaluation

To show that the functionalities described in the Chapter 7 were implemented successfully, for each use case an example scenario is written, in which all functionalities regarding the relevant guidelines are encountered. When re-playing this scenario with the demo, it becomes clear whether the application responds in the way that was intended, and whether the functionality was implemented successfully. After testing the scenario's, minor issues occurred, which could easily be solved by changing the code slightly. This chapter only describes the final run-through, which was successful regarding all functionalities.

8.1.1 Scenario TRI use case: G5 & G6

This section describes the run-through in the Camunda application of the example scenario regarding the TRI use case and its related functionalities. The example scenario is recorded in the screencast in the following link: `https://youtu.be/50pS8ywAztk`. This screencast provides the proof that the application is responding as intended by the functionalities regarding G5 and G6 in Table 7.1 and as described by the scenario.

Before describing the scenario, some explanation regarding the presentation of the results is required. Figures 8.2 and 8.3 show how Andy's and Deans physical load times increase during the course of the scenario, and what the physical load time limits are. These figures do not represent a dashboard, but simply illustrate how the (physical load) working times of Andy and Dean increase during the example scenario. Regarding the steps of the scenario described in Tables 8.2, 8.3 and 8.4, the times written like (m:ss) refer to the moments in time in the Figures 8.2 and 8.3, and the functionalities written like (FX.X) refer to the functionalities in Table 7.1, which are 'proven' in this part of the scenario. Now, the example scenario description starts.

Manager provides input in the Camunda modeler Before deploying the process model, the manager assesses the physical load tasks of the process. He fills in the input described in Table 8.1 regarding the three physically straining tasks (these are the red tasks in the process model in Figure 8.1) and regarding the "Lower cages over profiles" task.

Table 8.1: Input in the physical load extension in the Camunda modeler.

Task name	**Standing task?**	**Computer task?**	**Bad posture task?**	**Heavy lifting?**	**How much weight is lifted (in kg)?**
Pickup handful of profiles	Yes	No	Yes	Yes	15
Transport	Yes	No	No	Yes	15
Hang profiles one by one	Yes	No	Yes	Yes	15
Lower cages over profiles	No	No	No	No	30

The manager also takes a look at the limits, but sees no problem here, so leaves them as they are, which is (in seconds):

- standing - 50
- computer - 50
- badposture - 50
- heavy - 50
- sameload - 30
- weight - 25

After filling in these values, the process model for this example scenario as shown in Figure 8.1 was deployed in Camunda.

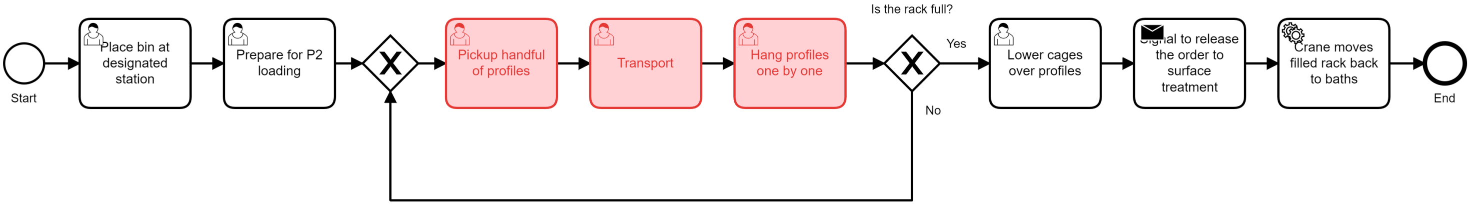


Figure 8.1: Process model of the manual loading process at TRI. Red tasks are tasks with the physical load risks for employees.

Andy, Dean and the manager use the Camunda application during execution of the work Andy and Dean are shop floor workers in the process, and in this example scenario, they go through the steps described in Tables 8.2 and 8.3 below. How their physical load working times increase during these steps is visualized in Figures 8.2 and 8.3. At the end of the scenario, the manager also performs some steps with the Camunda application which are described in Table 8.4. The Tables presenting the scenario steps are presented in chronological order, so first Andy starts working, then Dean, and then the manager performs some activities.

Table 8.2: The steps of worker Andy in the example scenario for the TRI use case.

Time (m:ss)	**Functionality**	**Step in scenario**
0:00		Andy starts working, logs into Camunda, sees that four orders have come in.
0:08		Andy completes the first three tasks of order 1, and his physical load times are updated after completing "Pickup handful of profiles"
0:08		Andy starts working on "Transport" for order 1.
0:27	F5.3	Andy receives the message "WARNING: you are at 80% of your sameload limit!".
0:30	F5.3	Andy receives the message "WARNING: you are at 90% of your sameload limit!".
0:33	F5.5	Andy receives the message "WARNING: you have reached the sameload limit, you have to choose a different kind of task, or take a break of at least 30 seconds!", is kicked off the task and put on a break.
...		Andy decides to wait for the break to be over.
1:03	F5.5	The break is over, and the task "Transport" for order 1 reappears in Andy's candidate task list.
...		Andy claims and completes the next two tasks for order 1.
...		Andy claims "Lower cages over profiles" for order 1 and receives the message "WARNING: this task is too heavy to perform alone, so Bert is going to help you.".
...	F6.1	Bert is assigned to the task "Help Andy with the Lower cages over profiles task".
...	F6.1	Bert and Andy to execute the task together.
...		Andy completes the "Lower cages over profiles" task, and the helper task is automatically completed as well.
1:07		Andy claims "Pickup handful of profiles" for order 2.
...		Andy receives warnings that he is approaching the standing and heavy limits.
1:23	F5.1 & F5.4	Andy is kicked off the task and can no longer claim or execute standing or heavy tasks.
...		Andy claims "Place bin at designated station" for order 3 and starts working on this task.

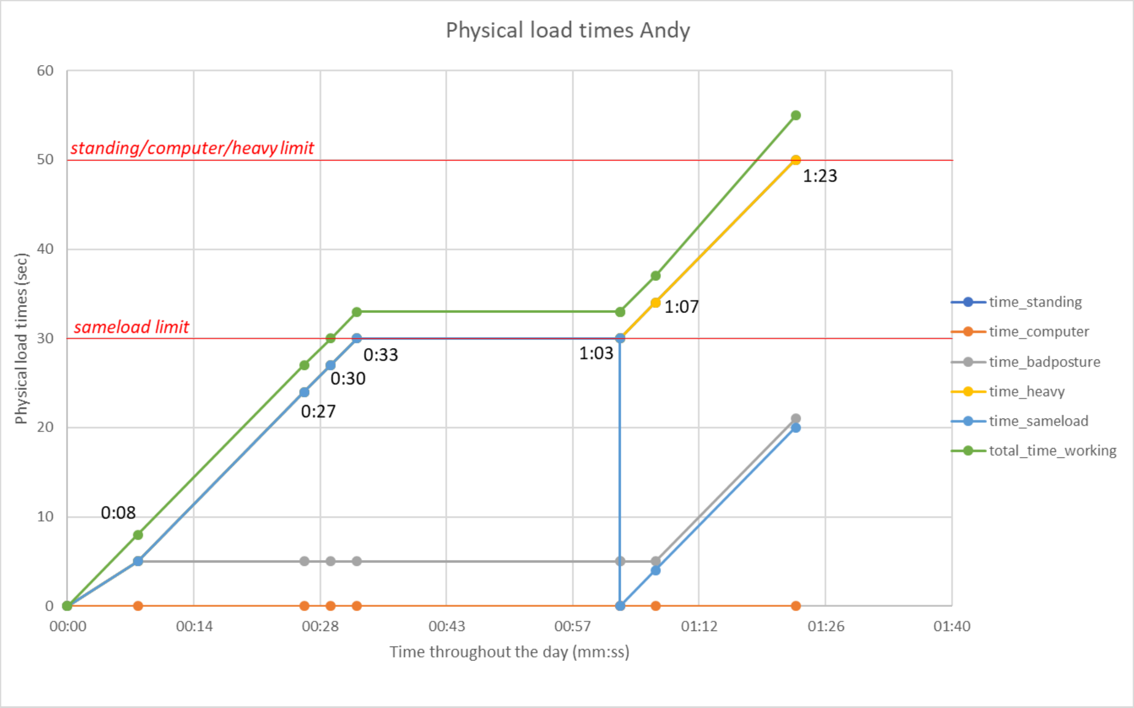


Figure 8.2: The physical load times of Andy during the run-through of the scenario

Table 8.3: The steps of worker Dean in the example scenario for the TRI use case.

Time (m:ss)	**Functionality**	**Step in scenario**
1:23		Dean starts working on different tasks regarding order 2 and order 4.
1:49		Dean claims "Hang profiles one by one" for order 2.
...		Dean receives warnings for several limits he is approaching.
2:09	F5.2	Dean quickly completes "Hang profiles one by one" for order 2 before reaching the limits. Although the limits are not fully reached, he can no longer claim tasks containing this type of physical strain.
...	F6.2	Dean tries to claim "Lower cages over profiles" for order 2 and receives the message "WARNING: This task is too heavy to perform alone, and no colleagues are available to help. Please try again later or choose a different task to work on."

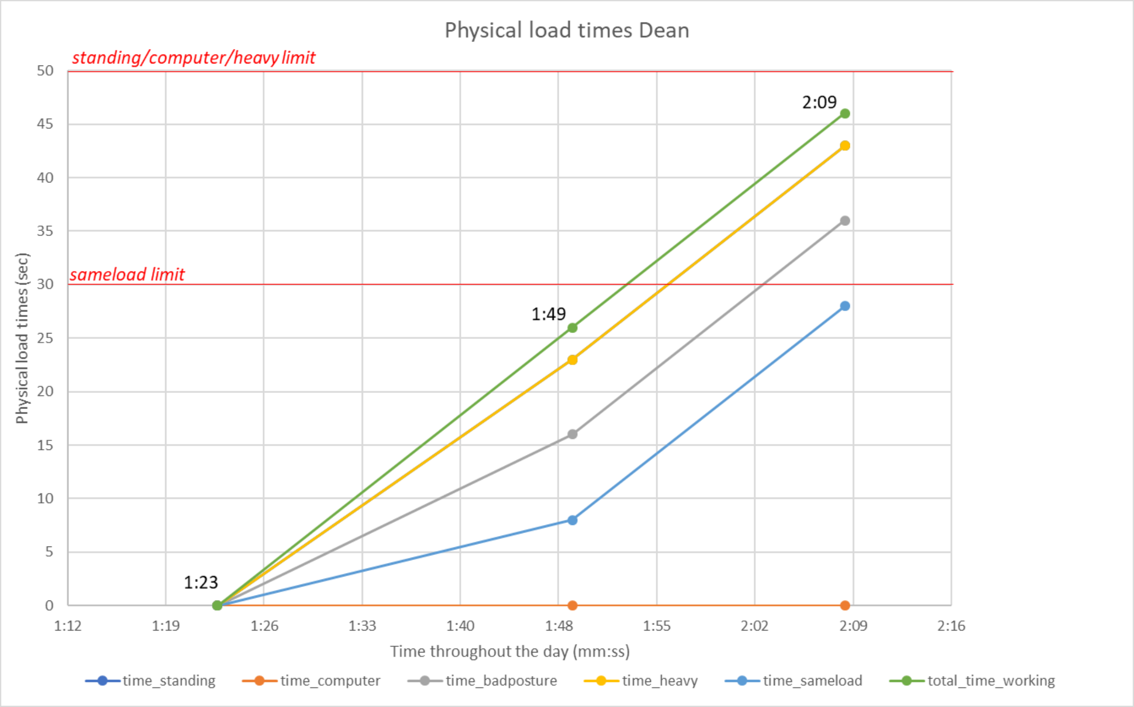


Figure 8.3: The physical load times of Dean during the run-through of the scenario

Table 8.4: The steps of the manager in the example scenario for the TRI use case.

Time	Functionality	Step in scenario
End of day		The manager shuts down the Camunda application at the end of the working day.
Start of new day	F5.6	The manager starts up the Camunda application, the physical load times of Andy and Dean were set to zero, and all tasks appear in their candidate task lists again.

8.1.2 Scenario Rossini use case: G2, G3 & G4

This section describes the example scenario regarding the Rossini use case, its related functionalities, and whether these were tested successfully after running through the scenario in the Camunda application. The exact same scenario is ran through and described in the screencast in the following link `https://youtu.be/W2V6Eoavgi8`. This screencast is also the "proof" that the application is responding as described below. The process model deployed in Camunda for this example scenario is shown in Figure 8.4. The process model differs slightly from the process model presented in Figure 7.3, since this version is extended with a ’Take break’ task. This was done to create some sort of ’break’ button in order for employees to take a break at any moment during their work, as described under the heading *BreakListener.java* in Section 7.3.2 of Chapter 7. In the scenario, specific parts of the story refer to the functionalities of Table 7.1. This is written like (FX.X) throughout the scenario description.

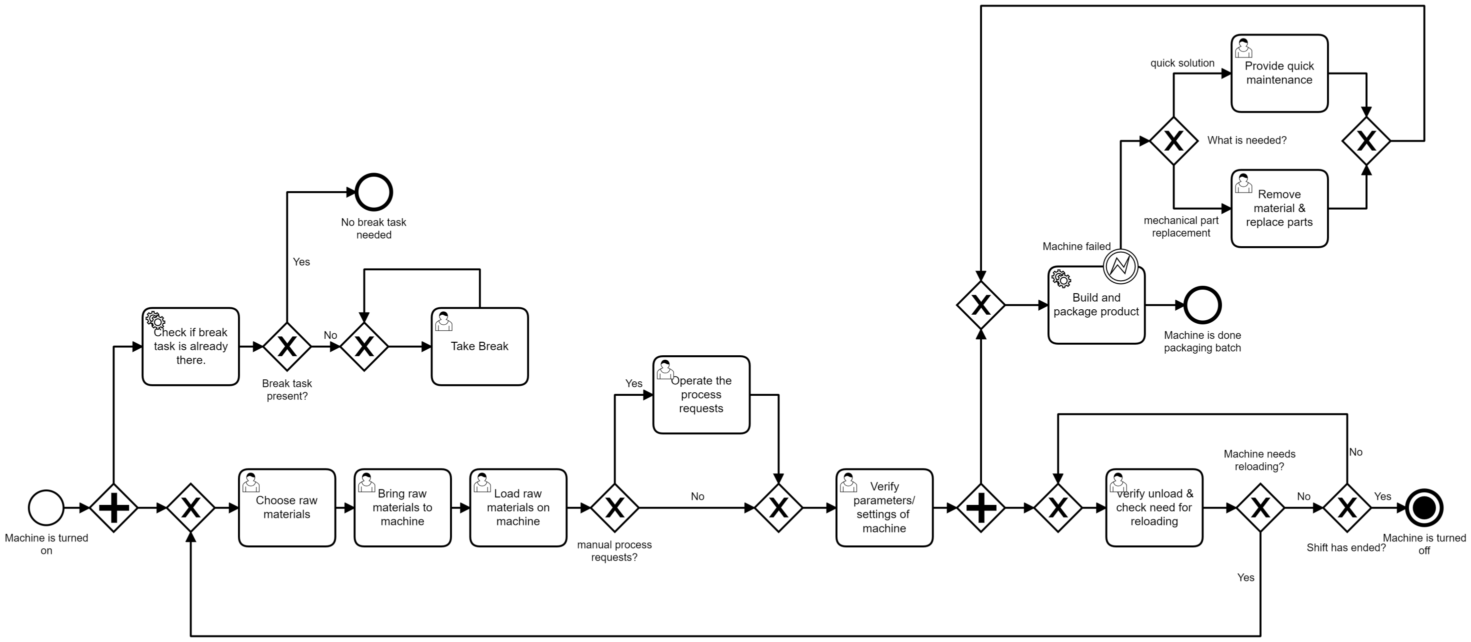


Figure 8.4: Process model of the packaging process at the Rossini pilot company.

Manager provides input in the Camunda modeler In this case, only the time someone is allowed to perform the same type of task, without a break or other task in between, is defined. The manager sets this sametask limit at 30 seconds in the Camunda modeler.

Chris uses the Camunda application during his work It is the start of the day, and today Chris is responsible for loading, unloading and fixing the food product packaging machines. The steps he goes through in this scenario are described in Table 8.5.

Table 8.5: The steps of worker Chris in the example scenario for the Rossini use case.

Functionality	**Step in scenario**
	Chris starts up the three machines.
F4.1 & F4.2	Chris can choose from his candidate task list for which machine he first wants to execute the task "Choose raw materials".
	Chris claims and completes "Choose raw materials" for machine 1.
	Chris claims "Bring raw materials to machine" for machine 1.
F3.1	Chris decides to take a coffee break, and claims the task "Take break".
	Eva walks into the work station.
F3.2	Eva wants to claim and complete "Bring raw materials to machine" for machine 1, but it does not appear in her candidate task list, because the task is 'waiting' for Chris to come back from his break.
	Chris comes back from his coffee break and completes the task "Take break".
F3.1	Chris is re-assigned to "Bring raw materials to machine" for machine 1.
	Chris completes "Bring raw materials to machine" for machine 1.
	Chris claims and completes all tasks related to starting the machines, after which all machines are busy packaging.
	The machines break down shortly after each other, so Chris starts working on the repair tasks.
F2.1	Chris starts to receive warnings that he is approaching the same task limit.
F2.2	Chris ignores the warnings and keeps working on the repair tasks, and therefore gets kicked off his current task.

F2.3	Chris is assigned to a break and can choose to wait for the break to be over or start working on another type of task.
F2.3	Chris waits for the break to be over, reclaims "Provide quick maintenance" and completes it.
	Chris claims "Verify unload & check need for reloading".
F2.1	Chris is tired and works slow, so after some time, he receives the message "WARNING: you are at 80% of your sametask limit!".
	Chris quickly completes "Verify unload & check need for reloading" before reaching the sametask limit.
F2.4	Chris wants to claim "Verify unload & check need for reloading" for one of the other machines, but the tasks have dissapeared from his candidate task list, because he is too close to reaching the sametask limit.
F2.4	Chris claims and completes "Provide quick maintenance".
F2.4	Chris's same task time is set to zero, "Verify unload & check need for reloading" reappears in his candidate task list.
	Chris claims and completes "Verify unload & check need for reloading".
	Chris turns off one machine.

8.1.3 Overall feasibility results

Based on the previously described scenario's and the execution of them as demonstrated in the screencasts, it can be concluded that alld defined functionalities of Table 7.1 were implemented successfully in the Camunda software.

8.2 Usability evaluation

To evaluate the usability of this manner of implementing the guidelines, a semi-structured interview was conducted with use case experts of both use cases. In order to gather information on different dimensions of usability, the Technology Acceptance Model (TAM) by Davis (Davis, 1985) was used as a basis for a part of the interview questions. This was done by preparing TAM statements as well as some open questions regarding each use case and performing a semi-structured interview with the resulting questionnaire with one use case expert for each use case.

For each dimension of TAM and each use case, some statements were prepared, which are shown in the Tables 8.6 and 8.7. The statements regarding Ease of Use and Perceived Usefulness are based on the original TAM as described by Davis (Davis, 1985). The question "How confident are you in this ratings?" was skipped for both dimensions. The statements regarding the Intention to Use dimension were based on a later research regarding the potential biases in the TAM (Davis & Venkatesh, 1996). In some researches regarding TAM, the order of questions was changed to prevent potential bias in the answers, but according to Davis's research (Davis & Venkatesh, 1996), this bias does not exist and in case of open questions, it is even better to not mix the questions. Since in this interview, also explanation was asked in some cases regarding the answers, this could be considered open questions, and therefore mixing the questions regarding the different dimensions is not suitable. In the following sections, the results regarding this usability evaluation are discussed for each use case separately.

8.2.1 Usability of supporting physical load (G5 & G6) in BPMS

The use case expert selected for the TRI use case is the managing director of the company. He was also closely involved in the HORSE project. The interview conducted with him consisted of three parts: an introduction to this project and demonstration of the application, in which the interviewee himself got to use the Camunda modeler to review the physical load tasks and this information is used in the demonstration of the behavior of the Camunda engine afterwards; reviewing this try-out and demonstration of the application with the TAM questionnaire; and finally some open questions. By letting him use the Camunda modeler, he is put in the position of a manager or team leader at TRI. The questionnaire used during the interview, which also consists of these sections, is shown in Appendix I.

The responses to the TAM statements, including any extra remarks if they came up, are listed below. The response to every statement is shown seperately and without its numerical value, because this is not a quantitative evaluation, and therefore conducting the average TAM score would not be of much value to the result of this evaluation.

Table 8.6: Results of the TRI interview regarding the TAM questionnaire

Perceived Ease-of-Use (PEU)		
Nr.	**Statement**	**Response**
S1	Learning how to use this application was easy for me.	Completely agree
S2	I find it easy to let the application do what I want it to do.	Strongly agree
S3	My interaction with the application is clear and comprehensible.	Completely agree
S4	I find the application flexible to communicate with	Completely disagree
S5	It is easy for me to become competent in using this application	Completely agree
S6	I find the application easy to use	Completely agree
Remarks: S2: Only if there would be an "execute" button, instead of you clicking/running three different programmes. And visualization of the output should be improved. S4: Answering "Yes/no" to physical load questions is not flexible. You should be able to input more options regarding movement, for instance a turning movement or a break of 2 minutes at the end of a walk.		
Perceived Usefulness (PU)		
Nr.	**Statement**	**Response**
S7	By using the application, monitoring and controlling the level of physical load experienced by the employees would take **less time**.	Completely agree
S8	Using the application would **increase my work performance** regarding monitoring and controlling the level of physical load experienced by the employees.	Completely agree
S9	Using this application would **increase the extent** to which I monitor and control the level of physical load experienced by the employees.	Completely agree
S10	By using the application, I would be **more effective** in monitoring and controlling the level of physical load experienced by the employees.	Completely agree
S11	Using the application would make it **easier** to monitor and control the level of physical load experienced by the employees	Completely agree
S12	I think the application is **useful** to monitor the level of physical load experienced by the employees.	Completely agree
Remarks: S7: Only if the application would work perfectly as intended. This is true for all questions! So incorporate more than only standing and lifting.		
Intention to Use (IU)		
Nr.	**Statement**	**Response**
S13	Assuming I have access to the application, I plan on using it	Completely agree
S14	Assuming I have access to the application, I predict that I would use it.	Completely agree

Results of open questions Apart from the TAM questionnaire, some open questions were used to enable a discussion on the usefulness of this application. These questions are shown in the questionnaire in Appendix I. The results of this part of the interview were summarized as follows:

- **Current management of physical load** Right now they don't rotate workers, the rotating every two hours was too expensive and cost too much time. So what now? They are looking for robotic solutions, or maybe eliminating the process. People walking around and rotating them cost too much time. Also, the physical load strain does not directly lead to health complaints, only happens after doing it for a few years.

- **Influence of application on other factors** When someone works in this process more often, a worker becomes trained/experienced, and can do it more quickly. The use case expert himself worked a shift the week before the evaluation, and estimates his output to be 70 percent of a regular worker. When the output is low, this costs substantially more money.
- **Predicted attitude of workers towards the application** People want a steady work place, they like routine, but they also complain about health complaints. If this was applied in practice, the company should train people to be able to work in all parts of the manufacturing line. This can be disadvantageous, because when people work somewhere more often, they get skilled, are able to multi task and can relax more during the work.
- **Strengths** When you implement this, process designers can see the problematic parts of the process. It also could be a good supporting tool in planning processes. Also the tool could be used to make employees more aware of the reason why they should rotate, and why their skills should be(come) more general.
- **Weaknesses** More input parameters should be related to the tasks like distance, time, mass, movements, which load is physically risky and which not. So a more extensive analysis of physical load would be better. Also, can we really estimate well what is heavy work and what is not? In this regard, using data from for instance sensors would be better. Lastly, the use case expert would use this as a last solution when dealing with physical load, first always try to find solutions related to the root-cause of the problem, so for example redesigning the process, implementing a robot, or eliminating the tasks or whole process.
- **Future possibilities** It would be interesting to use this kind of application for collecting data and learning, for example for robotic systems. Also, it could be used for redesigning processes. And in the long run, could you analyse if dropouts and absenteeism are related to the physical load? Finally, collecting more insights on energy and power needed to execute tasks, for instance with sensors or measuring devices, would be interesting.

8.2.2 Usability of supporting task variety (G2) and autonomy (G3 & G4) in BPMS

The use case expert selected for the usability evaluation regarding the Rossini use case is a team member of the TNO team of the Rossini project. He is experienced in job quality design and research. The interview had a similar structure as the TRI use case interview, but now, the interviewee is put in the position of the employee actually working in the process. This is done by letting the interviewee try out the Camunda tasklist after demonstrating how the application works. The questionnaire used for this interview is shown in Appendix J. Again, TAM-based statements were used to perform a qualitative analysis of the implementation and application of G2, G3 and G4. The results are shown in Table 8.7.

Table 8.7: Results of the Rossini interview regarding the TAM questionnaire

Perceived Ease-of-Use (PEU)		
Nr.	**Statement**	**Response**
S1	Learning how to use this application was easy for me.	Strongly agree
S2	I find it easy to let the application do what I want it to do.	Strongly agree
S3	My interaction with the application is clear and comprehensible.	Neither agree nor disagree
S4	I find the application flexible to communicate with	Disagree
S5	It is easy for me to become competent in using this application	Completely agree
S6	I find the application easy to use	Strongly agree

Remarks: S3: Right now, chosing the tasks is clear, and ordering the tasks based on priority is handy. The feedback is less clear since you see them in a small screen. S4: Not very flexible. It is flexible that you can choos tasks, but what I miss is that you can indicate what you personnaly find fun or important.		
Perceived Usefulness (PU)		
Nr.	**Statement**	**Response**
S7	By using the application, supporting autonomy and task variety in the job would take **-**.	
S8	Using the application would **increase the work performance** regarding supporting autonomy and task variety in the job	Completely disagree
S9	Using this application would **increase the extent** to which autonomy and task variety in the job are supported.	Neither agree nor disagree
S10	By using the application, autonomy and task variety would be supported **more effectively** in the job.	Agree
S11	Using the application would make it **easier** to support autonomy and task variety in the job	Agree
S12	I think the application is **useful** to support autonomy and task variety in the job	Agree
Remarks: S7: I don't know if currently autonomy and task variety are supported in any way, so I cannot compare it. S8: If there currently is no system: completely disagree, since autonomy automatically decreases when you automate, things will be adapted less to what the human wants. If there already is a system: agree, since then you will improve, since now, you DO take it into account. S9: Less autonomy when there is a system, but having to repair things every time a red light appears also is no autonomy, so it stays the same. S10: Yes, maybe you become more aware that you can make choices. S11: A bit the same situation as S10. S12: Could be, depends on the employee.		
Intention to Use (IU)		
Nr.	**Statement**	**Response**
S13	Assuming I have access to the application, I plan on using it	Neither agree nor disagree
S14	Assuming the company has access to the application, I predict that they would use it.	Completely disagree
Remarks: S13: I would be interested, but not in its current form.		
S14: No way		

Apart from the TAM statements, some open questions were asked to find more results on the usefulness of this application regarding autonomy and task variety. These results were summarized below:

- **Factors possibly influenced by the application** *Autonomy* could be negatively influenced due to the fact that you are automating. But it could also be positively influenced, since you can choose the tasks yourself. *Efficiency* can also be influenced positively or negatively. If you do it well, people could work more efficiently, but if people choose the wrong tasks, it is possible a machine is not working for too much time. *Interaction with colleagues* can decrease, since you are managed by a system instead of for example a supervisor which you speak to a few times during the day.

- **Reaction of workers** Some people, who get stressed out when they have to think about what they have to do during the day, will be happy with this kind of application. Sometimes it works the other way around, people get stressed out if they see a whole list of tasks they still have to execute.

- **Strengths** You see a list of what needs to happen, sorting based on priority is handy, gives a clear overview, while you still have the autonomy to decide what you want to do. By choosing yourself also task variety could increase. For some people, it would definitely increase the autonomy and task variety.
- **Improvement possibilities** It would be good to ask feedback from employees about how they liked the work today, and take this feedback into account to make the settings personal. Let them indicate preferences. For example physical load, some people like lifting heavy loads, others get back pains, so feedback is very valuable. So start with what most people like, and adjust this according to feedback of the employees. It is also good to think of how you let the application communicate to employees, so think of the user interface. For example warnings, how do you communicate this in such a way that it does not lead to extra stress and pressure.

8.2.3 Overall usability results

The usability results regarding the applications are varying. The usability results regarding the implementation of G5 and G6 are very positive: Only to one of the fourteen TAM statements the interviewee responded negatively. This statement refers to flexibility as part of the Perceived Ease-of-Use dimension, and is mostly related to the limited number of physical load variables available in the Camunda Modeler extension. In the responses to the open questions some doubts were mentioned regarding switching employees constantly, but overall, the attitude towards the demo was positive. The results regarding the implementation of G2, G3 and G4 are doubtful. The interviewee responded with both positive and negative ratings to the TAM statements, and also during the open questions, many implications of implementing the guidelines in this way were discussed. The main result from this evaluation is that the usefulness of implementing the guidelines in this way depends highly on the context in which the solution is implemented. The interviewee did see the potential benefits of the guidelines, but also stresses the negative effects a potential implementation might have.

Chapter 9

Conclusion

Job quality is a multidimensional concept and this research showed that the number of factors which influence the level of job quality is very high. Many work-design and job quality models exist, all of which present relevant factors of job quality. The biggest challenges regarding job quality in Industry 4.0 settings are posed by five of these factors: autonomy, task variety, social isolation, physical load and time pressure. Eight guidelines and twelve related variables were defined in this research regarding these job quality factors. Five of these guidelines (related to autonomy, task variety and physical load) were applied in practice, and this application was evaluated as feasible, but not necessarily as useful.

The evaluation showed that the usefulness of integrating certain job quality factors in a BPMS, is questionable. The main reason for this is that implementing automation, robots and/or a BPMS often leads to a lower job quality in terms of autonomy and task variety, although it can increase the job quality in terms of physical load. So although these factors are taken into account in a BPMS, it is still often lower or the same as compared to a situation without a BPMS. However, in some situations the automation or robotization has already taken place, and it is impossible or too expensive to change the solution. Then, implementing these kind of guidelines in the current systems can be useful and beneficial indeed, as compared to a situation with a BPMS which fails to integrate these guidelines. All in all, the main conclusion of this research is as follows:

Certain aspects of job quality in manufacturing processes can be integrated in a BPMS, namely by implementing variables and guidelines regarding autonomy, task variety and physical load. However, the extent to which such an implementation supports job quality depends on which job quality factor(s) will be supported by the BPMS and the context in which this implementation takes place.

9.1 Research limitations

Although this research has lead to some interesting insights regarding job quality and its integration into BPM software, there are also some limitations to its design and results.

The complexity of job quality First of all, this research has shown that it is indeed possible to integrate specific job quality guidelines into a BPMS. However, to integrate overall job quality, or support certain job quality factors fully, has proven to be a challenge too complicated to grasp within the scope of this research. During the analysis and diagnosis phase of the research, it became clear that a lot of factors influence job quality. The fact that so many things play a role, was dealt with by selecting the most relevant job quality factors for this research domain. However, the way these job quality factors might interact was not taken into account. For example the physical load and time pressure factors: forcing workers to keep within a physical load time limit probably leads to a higher time pressure, and therefore in total maybe even to a lower job quality. Also, often a lot of complexity is involved even within one job quality factor. An example is autonomy. Many implications arise when trying to find suitable guidelines to support this factor. Firstly, giving people more possibilities to make their own choices in their work in a BPMS, does not mean they will use these opportunities. This is the case in general; behavior of people is hard to change, and offering these kind of solutions should be accompanied with sufficient implementation and awareness raising. Secondly, the implemented functions in the system might be ignored, for example if a supervisor still forbids employees to take a break. Thirdly, maybe the guidelines will increase the autonomy of working with an already implemented BPMS, but this is probably not the case for work places where no BPMS is implemented yet. Letting a system allocate tasks to people and recording their working times sounds like employees have less autonomy than a situation in which no BPMS exists. Implementing a BPMS which lowers the autonomy, after which you try to increase the autonomy again by implementing the guidelines, seems inefficient. This does not mean that BPMS implementations should be discarded in any case, since many business outcomes other than job quality could be influenced positively by a BPMS implementation. But the extent to which such an implementation leads to gains and losses, especially in terms of job quality, should be researched in more detail.

The usefulness of run-time job quality solutions This leads to the next limitation of this research, namely the usefulness of approaching job quality from a run-time perspective. During the interviews, some interviewees had a clear opinion: job quality should be thought of during the *design* of a process, not during the execution. The TRI use case expert stated this as well: implementing a solution regarding physical load in his factory in this manner would be the last solution he would try. Therefore, it seems questionable whether it is useful to research job quality from the run-time perspective, instead of looking for solutions in the root-cause of the problem. This idea is discussed further in the next section regarding future research. Although this problem arose already during the analysis and diagnosis phase of the research, contrary opinions and perspectives supported the relevance of proceeding with the idea of run-time job quality solutions. For example, some interviewees mentioned situations in which a company already invested a lot of money in automation solutions, only to discover later its flaws regarding job quality. In such cases, it might be more beneficial to look for run-time solutions which can be implemented easily within the new process, instead of throwing away the whole investment. Therefore, it was useful to explore if and how job quality could be integrated in run-time BPM. All in all, arguments were made for both approaches, and since design-time solutions were out of the scope of this research, these were not investigated.

Requirements underlying the guidelines Another limitation became clear during the evaluation of the Rossini use case. Some strong assumptions lie at the basis of the proposed guidelines. In this case for example, it became clear that if only one worker is assigned to a manufacturing process, three of the eight guidelines are already irrelevant. This is because these guidelines (G1, G7 & G8) all assume that there are more workers in the production process to divide the tasks over or to socialize with. Another assumption regarding these guidelines is that workers are generalists and they can do different types of tasks. For example, if ten people work on ten different tasks in one workplace, but they can all do one specific tasks, it is still not possible to assign agents to different tasks regarding the same case (G1). These assumptions do not limit the usefulness of the conceptual solution framework, but they do limit the applicability of the solution. In other words, the process to which the framework is applied, or at least specific guidelines of the framework are applied, should comply to certain conditions.

Limited application and evaluation Lastly, both the application of the conceptual solution framework as well as the evaluation of the application were quite limited. Not all guidelines were applied and the original plan to apply the framework to three instead of two use cases fell through. This is partly due to time limitations and partly due to the COVID-19 situation taking place during the time. The third use case was planned to be based on one of the pilot use cases of the SHOP4CF project. However, due to the COVID-19 situation, it became hard to collect the information and details needed for the application in time. The same holds for the evaluation of the two use cases which were included. It was not possible to visit the factory of TRI at the time of the evaluation to see and analyze what is really happening in the process. Also, visiting the TRI factory or the Rossini team in real life would have made it possible to discuss the demo and the TAM questionnaires with more people at once. Now, only one person was interviewed per use case, and the evaluation interviews had to be performed digitally, which made it harder to go through the demo with the interviewees. All in all, the application and evaluation of the conceptual solution framework were less extensive than planned, which limited the results of this research phase in terms of both quantity and quality. Despite these limitations, the application of the framework to the two use cases covered most of the guidelines and the evaluation of both applications led to valuable results.

9.2 Future research

Although there were limitations to this research, its findings are still interesting and valuable, and lead to some new research possibilities.

Implement and evaluate full model First and foremost, the other guidelines in the conceptual model in 6.1 need to be applied and evaluated as well, to come to an overall conclusion of the complete conceptual solution framework. Unfortunately the use cases in this research did not cover the whole conceptual framework and therefore, future research is needed to implement and evaluate the other guidelines and variables in the model.

Design-time job quality solutions During the interviews, interviewees stressed that it is important to take into account job quality during the design of work processes instead of doing this during the execution of the work. During the interviews also some results were gathered regarding design-time solutions, but since this was out of the scope of this research, they were discarded for now. However, these results could be inspiring for a similar research to this one, focused on design-time: When analyzing or designing a process, which guidelines could be useful to follow in order to increase the job quality of people who will work in this process? To conclude, there is a need to also study design-time solutions regarding job quality in these kind of processes instead of (only) run-time solutions.

Extend physical load analysis During the TRI use case evaluation interview the interviewee stated that he likes the idea of modeling the physical load characteristics on an activity in a BPMN process model. He would be interested in such a solution, which is more extensive and flexible. The design of such a more extensive physical load analysis in BPMN was already performed by Polderdijk in her graduation research (Polderdijk, 2017). An example of future research to supporting physical load in run-time could be to implement the analysis tool of Polderdijk into Camunda, and let Camunda also respond to the other kinds of physical load described here. To make this work, more guidelines need to be defined regarding these other types of physical load.

Measuring job quality factors Lastly, a subject for future research could be to take into account real-time job quality measurements in a BPMS. This suggestion has been posed both during the interviews in the first phase of the research, as well as during the evaluation interviews. The use case expert of TRI suggested for example to measure in real-time how much energy and power people need to execute a certain task, and based on these data, define how physically straining a user task is. Another suggestion from the use case expert of the Rossini project is to let workers provide feedback in real-time and let them indicate their preferences regarding the work. These data can then be used by the system to adjust its settings to worker-specific needs, leading to a higher job quality. However, it is unclear how realistic these kinds of measurements are, in terms of technical possibilities, computing power and privacy. Nevertheless, it would be interesting to explore what could be done, and how useful this would be, taking these challenges into account.

All in all, a lot of interesting subjects to further investigate came to light during this research. Maybe, this research even resulted in more questions than answers, but this only shows that the subject of supporting job quality from a BPM perspective in the age of Industry 4.0 is still highly undiscovered, and a lot more research is needed to fill this gap of knowledge in its application domains.

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Appendix A

Literature review protocol

This appendix describes the literature review protocol followed for the literature research regarding job quality. The literature review type was defined according to Cooper's taxonomy (H. M. Cooper, 1988), and this definition is shown in Table A.1

Table A.1: The literature review definition according to Cooper's taxonomy (H. M. Cooper, 1988)

Characteristic	**Category**	**Description**
Focus	Theories	The focus is on what theories exist, what the relationships are and to what degree they have been investigated.
Perspective	Espousal of position	The review is qualitative and the researchers own position on the matter will bias the results.
Coverage	Purposive sample	The central or pivotal articles in the field will be selected.
Organization	Conceptual	The review will be organized according to the various theories in literature.
Audience	Specialized scholars	The audience of the review consists of scholars within (one of) the field(s) of this research.

The conducted literature review followed the stages as described by Cooper (H. Cooper, 1984). Below, for each of these phases, the relevant information regarding this particular literature review is presented.

Problem formulation The goal of the literature review is to define job quality and its factors. The questions guiding the literature review are therefore as follows:

- How can the concept "job quality" be defined?
- Which theories have been used to describe job quality and/or its factors?
- What are the dimensions and/or factors and/or determinants of job quality?
- How can the different dimensions and/or factors and/or determinants of job quality be categorized and structured?

To select useful reports to answer these questions, the following criteria for inclusion and exclusion were used.

1. The report is written in English or Dutch.
2. Job quality or a concept highly related to job quality (e.g. job satisfaction, worker well-being) is described as a result of (multiple) work-related factors.
3. The source of the report is reliable (e.g. it was suggested by a reliable source and/or the impact factor or number of citations suggest a high reliability)
4. The views in report can not only be used to describe job quality on a country level or continental level, but also on a per-job level.

Table A.2: Methods used to collect and select reports, and the resulting number of reports collected

Method	Details		Total
Expert suggestion	Experts: a work- and organizational psychologist, a human factors engineer and an ergonomist	+8	8
Electronic search	ABI Complete, search term: job quality, filter: last 3 years, date: 12-11-2019	+7	15
	ABI Complete, search term: job quality dimensions, filter: last 3 years, date: 12-11-2019	+3	18
	PsycINFO, search term: job quality (in Title), filter: 2010 - current year	+ 1	19
Selection round 1	Reading titles and abstracts, drop the irrelevant reports	-10	9
References	Reports found in the references of the reports which were evaluated as relevant up until now	+13	22
Selection round 2	Skimming through reports, drop irrelevant reports	-10	12
Selection round 3	Read complete text of reports, look up impact factor and nr of citations, drop irrelevant ones	-4	8

Data collection Relevant reports were collected according to three methods, namely:

- Suggestions of reports by experts in the field of the research subject(s).
- Electronic searches of academic databases.
- Searching reports from the references of already collected reports.

In total, 32 reports meeting the inclusion/exclusion criteria were collected by applying these three methods. The number of reports found by each method, and other relevant details such as search terms and names of the academic database, are described in Table A.2. Several selection rounds were executed to find the relevant reports which were finally used to find answers to the formulated problems. These selection steps are also described in Table A.2. In the end, the data collection phase lead to a selection of 8 reports. These reports are listed in Table A.3, including the number of citations and the Journal Impact Factor (JIF) as determined in 2018.

Table A.3: Final selection of relevant reports to be used

Nr	Author(s)	Year	Title	JIF (2018)	Citations	Reference
1	Cazes, Hijzen & Saint-Martin	2016	Measuring and Assessing Job Quality: The OECD Job Quality Framework	-	55	(Cazes et al., 2015)
2	Green, Mostafa, Parent-Thirion, Vermeylen, van Houten, Biletta & Lyly-Yrjanainen	2013	Is job quality becoming more unequal?	1.779	96	(Green et al., 2013)
3	Holman	2013	Job types and job quality in Europe	3.043	189	(Holman, 2013)
4	Osterman	2013	Introduction to the special issue on job quality: What does it mean and how might we think about it?	1.779	70	(Osterman, 2013)
5	De Bustillo, Fernández-Macias, Esteve & Antón	2011	E pluribus unum? A critical survey of job quality indicators	3.016	129	(Muñoz de Bustillo et al., 2011)
6	Leschke, Watt & Finn	2008	Putting a number on job quality? Constructing a European Job Quality Index	-	52	(Leschke et al., 2008)
7	Humphrey, Nahrgang & Morgeson	2007	Integrating Motivational, Social, and Contextual Work Design Features: A Meta-Analytic Summary and Theoretical Extension of the Work Design Literature	4.643	1853	(Humphrey et al., 2007)
8	Bakker & Demerouti	2006	The Job Demands-Resources model: state of the art	1.547	7517	(Bakker & Demerouti, 2007)

Data evaluation The selected articles were read fully and the information needed to answer the previously described problems was extracted by applying the following steps:

1. The information regarding an overall, general definition of job quality was extracted from each report.
2. The different dimensions/factors/determinants of job quality which exist according to each report were extracted.
3. The different ways of structuring job quality levels/dimensions/factors were extracted from each report.

Analysis and interpretation After applying the data evaluation steps, the information collected consisted of three lists, namely a list of general definitions, a list of job quality factors and a list of structuring ideas. To come to a good result, the following steps were applied to this collection of information:

1. The similarities and differences within the general job quality definitions were evaluated.
2. Based on these similarities and differences, and which kind of definition would be suitable for this research, the defnitions were merged into one final, general definition.
3. The job quality factors were merged into one final list of job quality factors by merging equal or similar job quality factors from different sources.
4. The dimensions named in some of the sources were used to create job quality categories.
5. The job quality factors were categorized according to the defined categories.
6. The different categories were structured according to levels, as suggested by one of the sources.

Public presentation The final presentation of the findings is in the form of two deliverables: The first deliverable is a general definition of job quality. This deliverable is one sentence stating the definition like this: "Job quality is ...". The second deliverable is a list of job quality factors structured according to categories and levels. This was done by making a tree-like structure starting with the concept "job quality" on the highest level, which is decomposed into "job quality categories" on the second level, which is then decomposed into "job quality factors" on the third, and sometimes also the fourth level. Also, categories on the second level and the job quality factors on the third and fourth level were categorized into three different levels. These final two deliverables can be found in the Chapter 5.

Appendix B

Interview Questionnaire semi-structured interviews (Q1, Q2, Q3 & Q4)

Interview Job Quality

Name:

Role:

Company:

Date:

Introduction:

- Research regarding job quality and BPM(S)
- Scoping: manufacturing and smart factories (human-robot cooperation)
- How can the quality of work be increased by means of BPMS?
- First phase: job quality, what is it, what is relevant, and what is possible from BPM

1. *How is your work related to the concept of "job quality", or to factors related to job quality?*

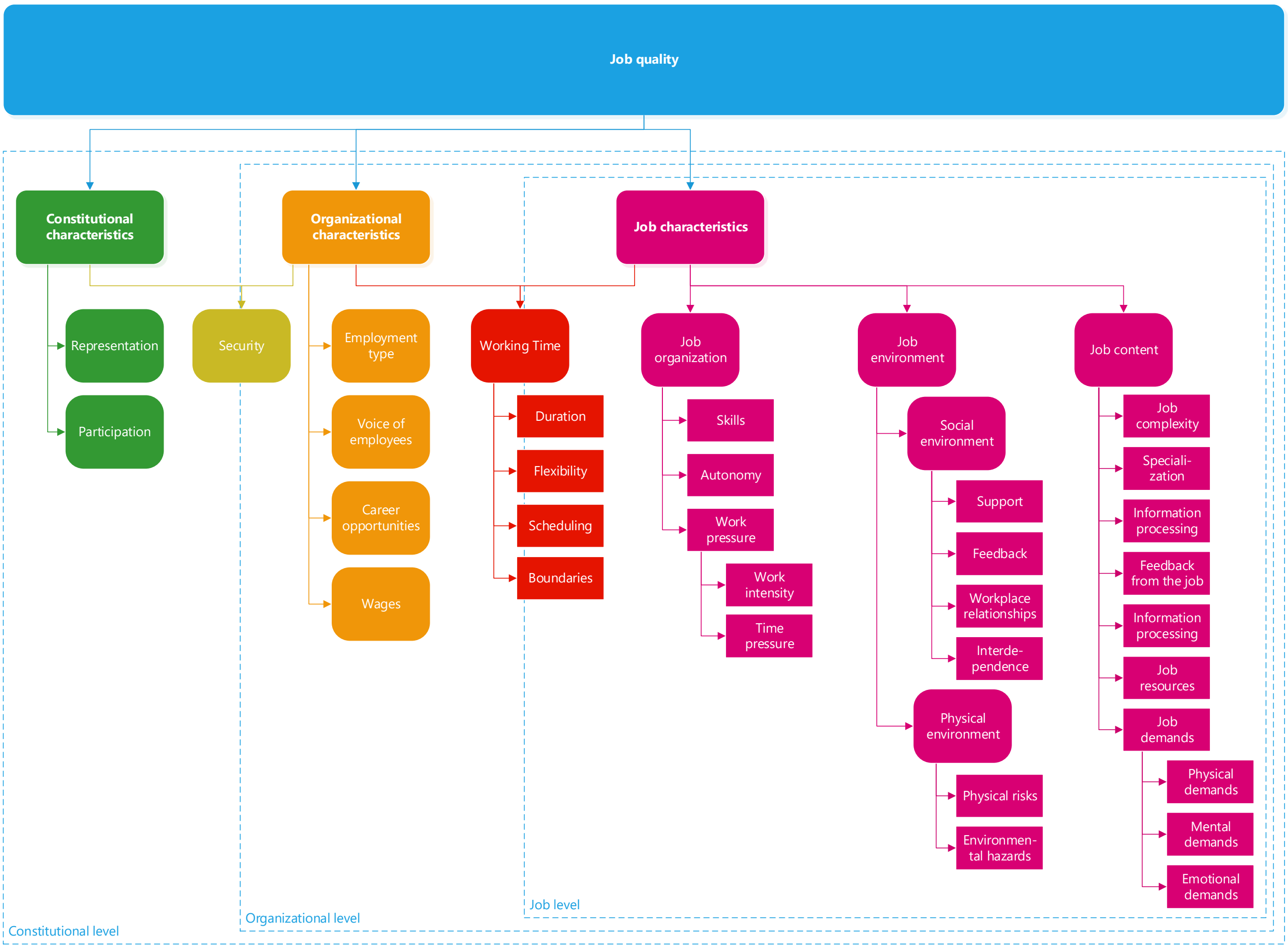
Definition of job quality:

2. *Which factors do you think affect the experience of a high or a low job quality?*

3. *Do you know any models/frameworks regarding job quality, or which are related to this subject?*

Explanation job quality model

- Literature research was performed regarding work design, job quality, etc.
- Findings were combined in the model below.


Job quality
Constitutional characteristics
Organizational characteristics
Job characteristics
Representation
Participation
Security
Employment type
Voice of employees
Career opportunities
Wages
Working Time
Duration
Flexibility
Scheduling
Boundaries
Job organization
Skills
Autonomy
Work pressure
Work intensity
Time pressure
Job environment
Social environment
Support
Feedback
Workplace relationships
Interdependence
Physical environment
Physical risks
Environmental hazards
Job content
Job complexity
Specialization
Information processing
Feedback from the job
Information processing
Job resources
Job demands
Physical demands
Mental demands
Emotional demands
Job level
Organizational level
Constitutional level

4. *When you look at this model, do you think it is complete? Or do you think there are still some things missing?*

Relevant job quality factors.

5. *When you look at the job quality model, which job quality factors do you think pose a challenge regarding working in a manufacturing company?*

6. *Do you think that the digitization/robotization of processes in manufacturing companies has changed this?*

7. *If so, what has changed? Which challenges disappeared? Which new challenges have arisen?*

8. *How can these challenges be tackled according to you?*

9. *Which factors regarding job quality momentarily lower the job quality in smart factories / in "smart" manufacturing environments / at the company you work?*

10. *Which factors regarding job quality could be improved in smart factories / in “smart” manufacturing environments / at the company you work?*

11. *How could these factors be improved?*

12. *Which factors regarding job quality which we have mentioned until now do you think have a priority? Which should be tackled at first?*

<u>Explanation BPMS</u>

- BPMS automatically assigns tasks to employees/robots and saves data.
- Using this data a BPMS can change the task allocation.
- Example: BPMS recrods the time that someone performs standing tasks, so after five hours, the BPMS assigns a non-standing task to someone, or inserts a break.

13. *If we consider the job quality factors which we have previously discussed, which information regarding these factors do you think should a BPMS be monitoring?*

14. *Which rules or limits should be complied to regarding these measurements?*

15. *Which of the previously mentioned measures and rules do you think are more important than others?*

Appendix C

Code list Q1

Table C.1: Codes of job quality factors and their description in Atlas.ti software.

Code	Description
Ambiance	Ambiance is related to the overall feeling and atmosphere in the workplace and between colleagues. If the ambiance is bad, it is hard to improve job quality.
Autonomy	Autonomy is a job quality factor. In general, more autonomy increases job quality, and less autonomy or more control decreases job quality.
Belongingness	Refers to the feeling of being part of a team, and belonging to a group of people or a company.
Climate	This is about the climate of the environment where you work, it can be hot or cold, moist or dry air.
Cognitive demands	Demands that require cognitive tasks to be fulfilled, so which are demanding regarding cognitive energy. For example tasks which require thinking, decision making or problem solving.
Conflict	When there is a conflict between yourself and a colleague, or between other colleagues, which influences your job
Conscientiousness	Personality trait of being careful or diligent.
Dangerous substances	Whether the job involves working with dangerous substances, like dangerous chemicals or odours.
Decision making	Whether the tasks in the job require you to make decisions, and also the level of imporantce of these decisions, responsibility.
Decision making autonomy	Whether you have the autonomy in your work to make decisions yourself
Depends on personal situation	If someone is very poor, the quality of other job characteristics is less important than the wage characteristics. If someone has enough money to live by, other characteristics of a job might become more important.
Employment type	Can be full-time, part-time, zero hours etc.
Environmental factors	Factors regarding the environment you are working in, for instance characteristics of the building, temperature, tools available, noise, etc.
Feedback	Do you get useful feedback from colleagues or managers.
Growth-need-strength	Personality trait defining how much you want to grow and develop in your work in general.
Heat-producing machinery	Are you working with (dangerously) heat producing machinery.
Income	How much wages you earn for the job.
Isolation	Are you working together a lot with colleagues or working on your own all day (isolated).
Job complexity	The level of complexity of the tasks within the job.
Job content	The content of the tasks within the job, examples are job complexity, cognitive demands, physical demands, decision making.

Job crafting	The amount to which someone (can) restructure or reorganize their own work within a job.
Job demands	The things within a job that are demanded of an employee, that cost energy to fulfill.
Job Resources	Things inside a job that give the worker the tools and energy to meet the job demands.
Job security	Whether someone can be secure to stay in a job or can be fired every moment of time. Also, the security of an income, even if the job is lost.
Knowledge & skills	The use of knowledge and skills required by the work.
Law	Laws around working and employment, for example minimum wage.
Learning & development opportunities	The extent to which there are opportunities in the job to learn and develop.
Meaningfulness	The extent to which the job is meaningful or significant or important.
Organisational structure	The way the organization is structured, for example functional teams or matrix.
Perceptive-cognitive load	Highly related to cognitive demands. The workload which is not physical or emotional, but requires thinking and problem-solving.
Personal resources	The type of education and work experience someone has personally which could be beneficial in the job.
Personality	Personality characteristics which could increase or lower the work-person fit.
Physical demands	The demands which require physical energy, for example lifting or pulling.
Physical load	The amount of physical demands in a task, for example one hour of lifting 10 kg.
Physical working conditions	The physical environment, so climate, noise, etc.
psychosocial factors	The social environment, so ambiance, support etc.
Psychosocial load	psychosocial factors that need energy, for instance conflict.
Safety	Safety related factors, for example safety around machines/robots, safe lifting.
Scheduling autonomy	The autonomy to schedule work the way you want to. For example decide on order of tasks.
Self efficacy	An individual's belief in his or her capacity to execute behaviors necessary to produce specific performance attainments.
Skill variety	The extent to which you need to use different skills throughout the job.
Social context	The social context of the job, so who are your colleagues, do you have good relations, etc.
Social support	The extent to which you get social support at work, for instance support from colleagues in performing a difficult task
Sound	The amount of noice present in the working space.
Task identity	The extent to which one worker performs a process from start to end, or just one small task in the process.
Task variety	The extent to which someone performs different tasks or constantly the same tasks.
Time pressure	The work pressure experienced by time, for instance work pressure due to unreachable targets.
Work methods autonomy	The autonomy to decide yourself how to perform tasks, which methods to apply to fulfill the job.
Work postures	The postures which you have to take while performing the work.
Working conditions	The conditions set by the employment contract around your employment and work.
Working relations	Relations with the people you work with or work for.
Workload	The amount of work that needs to be performed. Can be physical or cognitive.
Work-person fit	The extent to which someone's personality, personal resources and personal preferences fit the job.

Appendix D

Job Quality Factors Network in Atlas.ti

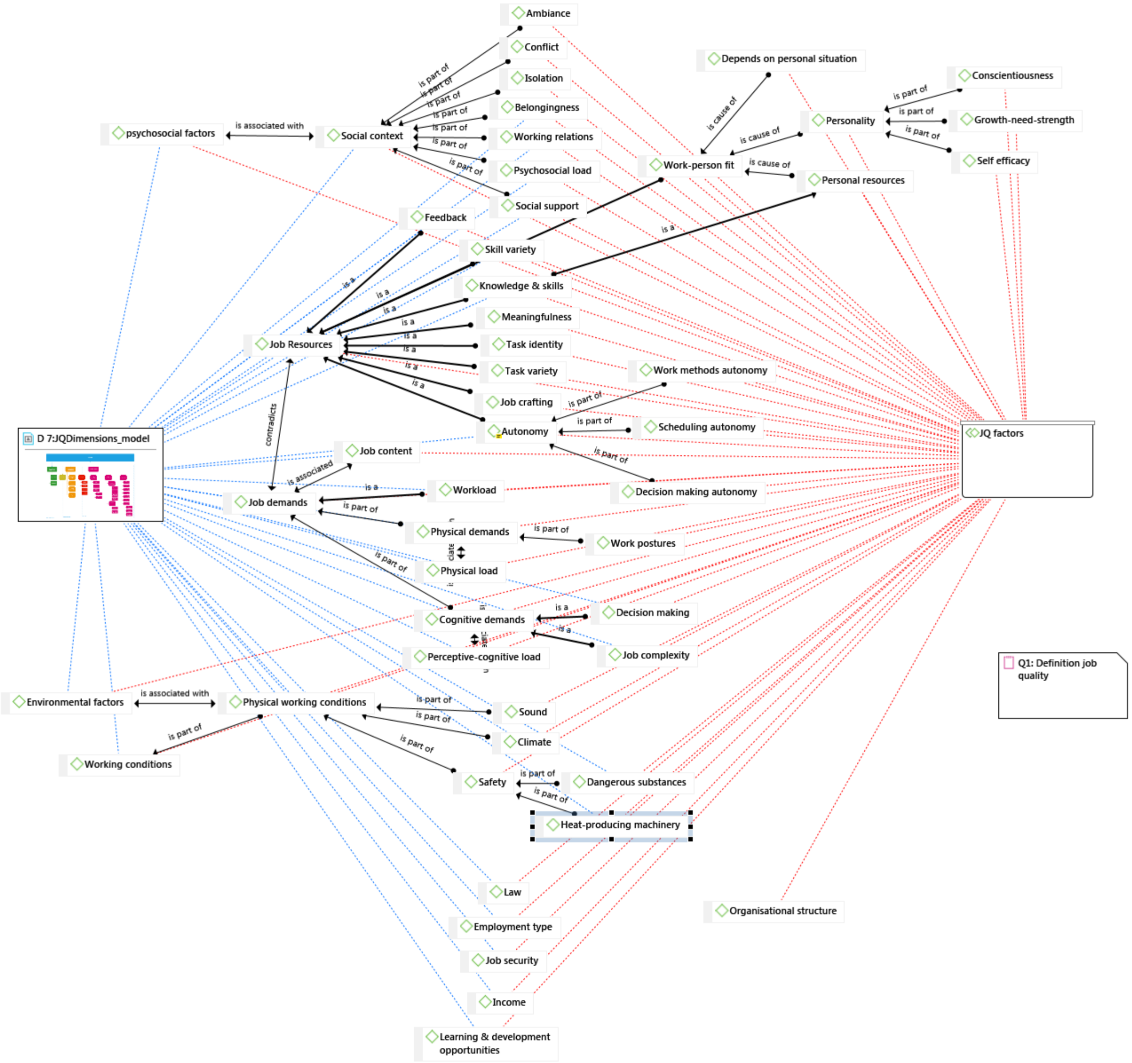


Figure D.1: Network linking codes of literature findings regarding job quality factors to the codes of interview findings regarding job quality factors in the Atlas.ti software.

Appendix E

Code list challenges (D2a)

Table E.1: List of job quality challenges codes and their description and code group in Atlas.ti software (D2a).

Code	**Description**	**Code group**
Bad environment	The physical environment in which the work takes place is not comfortable or organized in a nice way.	JQ challenges manufacturing relevant
Bad postures	Some things cannot be robotized, for instance tasks where you have to work in a bad posture, so the amount of bad postures increases.	JQ challenges robotization/automation relevant
Dangerous substances relevant	Working with dangerous substances and the safety around this is an issue.	JQ challenges manufacturing relevant
Design process from technology perspective	Processes are designed from a technology perspective (what can technology do?) instead of a human perspective (what do we want technology to take over?)	JQ challenges robotization/automation relevant
Factors impact each other	Often the problem lies not just within one job quality factor, improving one factor can increase the job quality regarding other factors as well.	JQ challenges robotization/automation relevant, JQ challenges manufacturing relevant
Fear of job loss	Employees are scared that robots take over their job and they will lose their job.	JQ challenges robotization/automation relevant
Foreigners lower job quality standard	In some cases foreigners agree to do bad jobs because the pay is better in the Netherlands. When this happens, the incentive for employers to improve the job quality dissapears, because they can better let the foreigners do the jobs than invest a lot in job quality.	JQ challenges manufacturing relevant
High level of change in processes	In manufacturing processes the problem occurs that processes change quite frequently and that people constantly have to change their working accordingly.	JQ challenges manufacturing relevant
Higher cognitive demands	There is a shift from physical demands (assembling yourself) to cognitive demands (checking of robot assembles it right, check status of machine etc.)	JQ challenges robotization/automation relevant
Higher control	Increasing digitization leads to higher control from managers, they have more insight in the work.	JQ challenges robotization/automation relevant
Higher feedback	Since more data is collected regarding speed and quality of the work, it is easier to see if you do your work right.	JQ challenges robotization/automation relevant
Increased work pressure	Since robots/machines can do things faster, people also have to work faster, or when a robot breaks down, you have to make up for it, increasing the work pressure.	JQ challenges robotization/automation relevant

Increasing computer work	With the digitization more computer work arises.	JQ challenges robotization/automation relevant
Influence of robotization is context-specific	Robotization does not have the same impact in every setting, highly depends on the kind of robot, what it replaces, how it influences the process etc.	JQ challenges robotization/automation relevant
Job crafting increases	People have to learn new ways to work with the machines/robots, which increases job crafting.	JQ challenges robotization/automation relevant
Keep people focused	The challenge is to keep people focused when the tasks in the job are fairly simple/repetitive/monotonous.	JQ challenges manufacturing relevant
Knowledge of people gets lost	Sometimes automation/robotization is implemted without taking into account the knowledge the robot doesn't have but the people do.	JQ challenges robotization/automation relevant
Less annoying tasks	When robots only do the annoying tasks, robotization has a positive effect.	JQ challenges robotization/automation relevant
Less physically heavy jobs	When robots/machines take over physically heavy jobs, the level of physically heavy jobs decreases.	JQ challenges robotization/automation relevant
Less social interactions	Working with robots decreases the level of social contact during working. More and more people are standing alone or too far from colleagues to chat, large parts of the day	JQ challenges robotization/automation relevant
Low level of development opportunities	In manufacturing, generally there is a low level of development opportunities.	JQ challenges manufacturing relevant
Lower autonomy	In manufacturing processes, as well as in increasingly automated/robotized processes, the autonomy of workers decreases.	JQ challenges robotization/automation relevant JQ challenges manufacturing relevant
Lower job complexity	Tasks get simplified to create a process suitable for robotization, leading to a lower job complexity	JQ challenges robotization/automation relevant
Lower task identity	Because parts of the process are taken over, human resources only do small parts of the whole process, lowering the task identity.	JQ challenges robotization/automation relevant
Lower task significance	It can feel like the small part you are doing is not as important anymore, important parts are taken over.	JQ challenges robotization/automation relevant
Machines break down a lot	If machines are not fully developed or working optimally yet, they can break down, slowing down the process.	JQ challenges robotization/automation relevant
Monotonous work	The work becomes repetitive and boring, with a low level of variety.	JQ challenges robotization/automation relevant JQ challenges manufacturing relevant
Only "bad" tasks remain	The bad parts of the job are not robotized, only the good parts, so the humans relatively have to spend more time on bad jobs.	JQ challenges robotization/automation relevant
Only improve until acceptable norms	Employers only improve things until they meet acceptable job quality norms, they do not invest any further.	JQ challenges manufacturing relevant
Opportunities not used	Opportunities to arrange work positively around automation/robotization are not used, for instance more task rotation, often not applied.	JQ challenges robotization/automation relevant
People design better work for themselves/friends	Research shows that people design worse work for people they don't know. This is a problem since managers design work for employees they are not in touch with, or work they don't have to do themselves.	JQ challenges robotization/automation relevant
People don't want to do jobs	People don't want to do the simple/bad jobs anymore, so it is hard to find employees for the job.	JQ challenges manufacturing relevant
People leave "bad" jobs	Employees leave their job because the jobs that remain are not good enough.	JQ challenges manufacturing relevant

Physical heavy workload	In manufacturing processes, the physical workload of some tasks is too heavy.	JQ challenges manufacturing relevant
Physical working conditions relevant	In some manufacturing environments the physical working conditions are not good enough.	JQ challenges manufacturing relevant
Pride of robotized work	Employees think it is cool that they are working in an environment with high-tech machines or robots.	JQ challenges robotization/automation relevant
Repetitive movements	Some manufacturing processes require a high level of repetitive movements, which is physically too heavy.	JQ challenges manufacturing relevant
Robots/machines fail	The robots or machines are not working as they were supposed to, so they have to be taken away because humans do it better.	JQ challenges robotization/automation relevant
Safety relevant	The safety in some manufacturing processes is not acceptable	JQ challenges manufacturing relevant
Simplification of tasks	Tasks get simplified, lowering the job complexity and the skill level needed for the task	JQ challenges robotization/automation relevant
Skills needed change	The job changes due to automation/robotization, and therefore also the skills. For instance mechanics have to be more social, because technical part is taken over.	JQ challenges robotization/automation relevant
Standing for a long time	Some manufacturing processes or tasks require standing for too long.	JQ challenges manufacturing relevant
Time pressure increases	Deadlines are tighter, targets higer, since robots/machines are fast, so the time pressure for human tasks increases as well.	JQ challenges robotization/automation relevant
Unbalanced physical vs mental demands	When all physical things are taken over, only cognitive tasks remain, while physical tasks can be a nice change to give your brain a rest during working.	JQ challenges robotization/automation relevant
Unequal benefits/disadvantages	Managers benefit from digitization, since they have more insight in performance levels, while employees have more disadvantages, because they experience a higher level of control and less autonomy.	JQ challenges robotization/automation relevant
Unreachable targets	The targets are becoming more difficult to reach in time, everything has to be done quicker and quicker.	JQ challenges manufacturing relevant
Work content changes	The work content often does not dissapear but changes. Instead of doing a task, you have to monitor a machine that is doing the task.	JQ challenges robotization/automation relevant
Work design often about splitting tasks	The work is designed wrongly because people often tend to split work up in little tasks, which is not beneficial for human resources.	JQ challenges robotization/automation relevant
Work pressure high	The work pressure in manufacturing is currently high.	JQ challenges manufacturing relevant
Workforce changes	Instead of teaching employees new skills, it is easier to just hire new people with the necessary skills.	JQ challenges robotization/automation relevant
Wrong assumptions of management	Management assume things about employees and their opinion about work which are wrong, for instance: they had a lower education, so they won't mind to do things this way.	JQ challenges other relevant

Appendix F

BPM-related job quality factors (D2b)

Table F.1: A list of BPM-related job quality factors, and BPM-related improvements regarding the job quality factors (D2b).

Job Quality Factor	BPM-related improvement	Design/run-time?
Boundaries (working time)	Limit the total working time in a specific time unit (day, week, etc.) or on a specific task. For example, a BPMS can intervene when someone has been doing to much overtime outside his or her regular working hours.	Run-time
Conflict	When there are tasks which require cooperation, do not let people work together who are in conflict or have a high risk of getting into conflict. For example, a manager could insert bad combinations of employees in a BPMS, which then can make sure these people never work together. Or, only design tasks and processes which do not require cooperation.	Design-time
Decision making	Create tasks which require more decision making. Or, assign the already existing decision making tasks more often to an employee with a low level of decision-making in his/her job.	Both
Decision making autonomy	Design tasks in which decisions can be made by the employee if they want to, or authorize employees to make more decisions if they want to.	Both
Duration (working time)	Limit the duration of specific tasks, by for example implementing working time limits in a BPMS. Or split tasks so they can be finished the next day, so the total working time on a day is decreased.	Both
Feedback	Design specific feedback tasks for employees to give each other feedback and implement these in a process. Or, implement a feedback moment at specific moments in time, for example by letting a BPMS ask people to give feedback after finishing a task together.	Both
Feedback from the job	Let a BPMS return feedback based on performance indicators, for instance, a BPMS can show if you performed a task quicker or slower than the company average.	Run-time
Flexibility (working time)	Design more tasks in a process in parallel, so it is easy to plan shorter or longer tasks dependent on the desired working time. Or, let people have the option to take breaks during or in between tasks.	Both
Interdependence	Design tasks which make colleagues more interdependent, for example make sure the output of one employee's work is the input for someone else's work, instead of creating a complete process executed by one employee. Or, implement a rule in a BPMS which ensures that someone else's task not can start until the previous one by a colleague is finished.	Both

Isolation	Design team-based tasks/processes or let a BPMS alternate isolated tasks between cooperative tasks. For example, a BPMS could assign a task to the worker who has had the longest "alone" time.	Both
Job crafting	Design tasks which are not defined very specifically to encourage job crafting, or don't prescribe every step in a task in a BPMS, in order to encourage people to craft their job.	Both
Learn and development opportunities	Design specific tasks in processes which are focused on learning and developing.	Design-time
Organizational structure	Organize processes in a team structure instead of a functional structure, or the other way around, based on what the employees need to experience a higher level of job quality.	Design-time
Physical load	Change the product design to seperate one heavy task into two less heavy tasks, which can be divided amongt employees. Or, let people work together on heavy tasks or let a BPMS rotate the assignment of heavy and less heavy tasks.	Both
Scheduling autonomy	Design tasks as much in parallel as possible, so working time can be scheduled freely. Or, let worker instead of manager decide which tasks to execute when.	Both
Scheduling (working time)	Design tasks in a process to be less dependent, for example more parallel tasks, so tasks can easily be rescheduled to another moment in time. Or, give people the option to reschedule tasks to another moment.	Both
Skill variety	Design more skill varied tasks in one process, or rotate employees more on tasks requiring different kinds of skills, to increase the skill variety of each employee.	Both
Social support	Design tasks or processes for teams instead of individuals, so people work together and can socially support each other.	Design-time
Task identity	Design a process in such a way that it can be executed by one employee from start to end, or let a BPMS assign an employee to all tasks within the process of one product, instead of just one task.	Both
Task variety	Design varying task within a process, or rotate different kinds of tasks among employees to increase task variety.	Both
Time pressure	Design risky or highly time-related tasks earlier in the process, to decrease time pressure. Or, divide tasks with risks regarding time pressure among employees to lower the time pressure per person.	Both
Work-methods autonomy	Design tasks which can be performed in different ways, or don't prescribe or control the method of execution of a task in a BPMS.	Both

Appendix G

Collection of solution ideas Q3

Table G.1: Collection of BPMS job quality solutions, rules or mechanisms from literature and other sources

JQ factor(s)	**Solution/rule/mechanism**	**Source**	**Model candidate?**
(Decision making) autonomy	Decisions in a process should be executed by an employee, and should not be automated.	(Vanderfeesten & Reijers, 2006)	No
(Decision making) autonomy	Empower: give workers most of the decision-making authority instead of relying on middle management.	(Dumas et al., 2013)	No.
(Decision) autonomy	Give employees the possibility to send a work item to another employee, who is better in performing the job, who has more knowledge about the case, who is not busy, etc.	(Vanderfeesten & Reijers, 2006)	Similar to other rule
(Decision) autonomy	Give employees the possibility to reject a work item (with a valid reason) and return it to the workflow enactment service.	(Vanderfeesten & Reijers, 2006)	Yes.
(Scheduling) autonomy	Offer an employee "batches" of work items. In this way, the batch is pushed, but the employee can choose the order of execution of work items within this batch.	(Vanderfeesten & Reijers, 2006)	Similar to other rule
(Scheduling) autonomy	Do not specify in what order parallel activities should be executed	(Vanderfeesten & Reijers, 2006)	Similar to other rule
(Scheduling) autonomy, (decision-making) autonomy	Selection autonomy: The ability of resources to select a work item for execution based on its characteristics and their own preferences	(Russell et al., 2004)	Yes
(Scheduling) autonomy, physical load	Give employees the freedom to go on a break when they feel the need to take a break	(TNO, 2018)	Yes
(Work methods) autonomy	Do not "over-specify" the content of an activity. When it is possible to have an amount of freedom in executing the activity, this freedom should be used. For example: when there are several ways to produce the output of an activity, let the employee choose in which way he wants to perform the activity.	(Vanderfeesten & Reijers, 2006)	No.
Autonomy	Give employees the opportunity to adjust the appearance of work items in their worklists to their own preferences: FIFO, earliest due date, random, etc.	(Vanderfeesten & Reijers, 2006)	Yes
Autonomy	Let an employee choose work items from the private worklist himself/herself: pull-mechanism	(Vanderfeesten & Reijers, 2006)	Yes
Autonomy	Use a shared worklist, from which an employee can choose himself/herself: pull-manner	(Vanderfeesten & Reijers, 2006)	No
Autonomy	Resource-Initiated Execution - Offered Work Item: The ability for a resource to select a work item offered to it and commence work on it immediately	(Russell et al., 2004)	Yes

Autonomy	Resource-Determined Work Queue Content: The ability for resources to specify the format and content of work items listed in the work queue for execution	(Russell et al., 2004)	Similar to other rule
Autonomy, task variety	Use shared worklist from which an employee can choose himself	(Vanderfeesten & Reijers, 2006)	No
Autonomy, task variety	Create "team batches" of work items. A team of employees (having the same competences/roles) can divide the work according to their own preferences.	(Vanderfeesten & Reijers, 2006)	No
Autonomy, task variety	Offer a variety in work items to an employee. Remember the kind of work items an employee has executed and decide, based on this history, what kind of new work items will be offered to him or her.	(Vanderfeesten & Reijers, 2006)	Yes
Isolation	Create "team work items". Employees (with different competences) have to cooperate to execute an activity.	(Vanderfeesten & Reijers, 2006)	Yes
Physical load	If the load to lift and/or carry is over 25 kg, carry with two people, with a maximum of 50 gk.	(NRK, 2010b)	Yes
Physical load	Rotate heavy lifting/carrying/pushing/pulling tasks	(NRK, 2010a), (InPreventie, 2020c)	Similar to other rule
Physical load	Insert breaks in heavy pushing/pulling tasks	(InPreventie, 2020c)	Similar to other rule
Physical load	Rotate bad posture tasks	(*Werkhoudingen*, 2020)	Similar to other rule
Physical load	Maximum of 2 hours/day in an unfavorable posture	(5xbeter, 2020)	Yes
Physical load	Maximum 4 hours/day standing tasks	(5xbeter, 2020)	Similar to other rule
Physical load	Maximum 6 hours/day standing in a permanent sport of 1 square metre	(NRK, 2010a)	Yes
Physical load	Rotate standing and walking tasks	(InPreventie, 2020b)	Similar to other rule
Physical load	Maximum of 2 hours computer work at a time	(InPreventie, 2020a)	Yes
Physical load	Maximum of 6 hours computer work per day	(InPreventie, 2020a)	Yes
Physical load	Separation of Duties: The ability to specify that two tasks must be allocated to different resources in a given workflow case. When next (heavy) task is allocated to someone else, this decreases physical load per person.	(Russell et al., 2004)	Similar to other rule
Physical load	Suspension/Resumption: The ability for a resource to suspend and resume execution of a work item.	(Russell, van der Aalst, Ter Hofstede, & Edmond, 2005)	Yes
Physical load	Deferred Allocation: The ability to defer specifying the identity of the resource that will execute a task until run-time. Useful when you want to select resource based on data.	(Russell et al., 2004)	Yes
Physical load, task variety, time pressure	Avoid monotonous and time bound work as much as possible. If not possible, reduce this kind of work as much as possible. If varying the work more is not possible, insert enough breaks	(*Werkhoudingen*, 2020)	Similar to other rule
Physical load, social isolation	Additional Resources: The ability for a given resource to request additional resources to assist in the execution of a work item that they are currently undertaking.	(Russell et al., 2004)	Yes
Physical load, task variety, isolation	History-based allocation: The ability to offer or allocate work items to resources on the basis of their previous execution history.	(Russell et al., 2004)	Yes

Task variety	Case assignment: let workers perform as may steps as possible for single cases	(Dumas et al., 2013)	Yes
Task variety	Specialist-generalist: Consider to deepen or broaden the skill of the resources	(Dumas et al., 2013)	No
Task variety	Case Handling: The ability to allocate the work items within a given workflow case to the same resource.	(Russell et al., 2004)	Similar to other rule
Task variety, physical load	Stateful Reallocation: The ability of a resource to allocate a work item to another resource without loss of state data.	(Russell et al., 2004)	Yes
Task variety, physical load	Insert one or more relaxing moments in monotonous work to relax someones muscles	(NRK, 2010a)	Similar to other rule
Time pressure	Flexible assignement: assignw ork in such a way that maximal flexibility is preserved for the near future.	(Dumas et al., 2013)	No.
Time pressure	Late Distribution: The ability to advertise and allocate work items to resources after the work item has been enabled. You don't see a whole list of work items.	(Russell et al., 2004)	Yes
Time pressure, physical load	Make sure the speed of the execution of precision work can be chosen freely, instead of forcing a given speed	(TNO, 2018)	No

Appendix H

Solution-challenges network regarding guideline ideas from the interviews for Q3

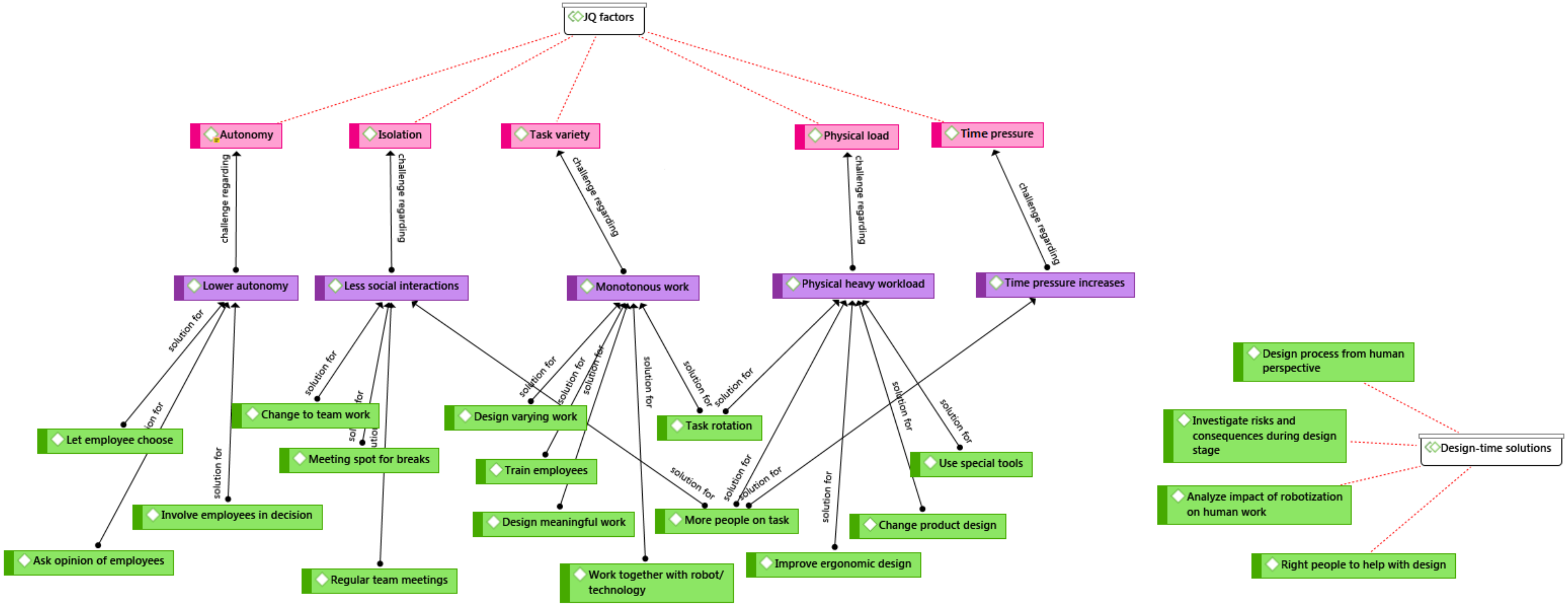


Figure H.1: Network showing the codes regarding BPMS solution ideas posed by interviewees, linked to the challenges and job quality factors.

Appendix I

Interview questionnaire for usability evaluation TRI use case (Q7b)

Use Case Expert interview – Usability evaluation – Guideline 5&6

Use case: Thomas Regout International (TRI) – manual loading of profiles

Interviewee: Ruud (Director of operations at TRI)

Introduction

- Introduction to each other:
    - Eva: Graduating for master BIS (combination of industrial engineering and informatics), Irene is supervisor.
    - Ruud:
        - *What is your role in the company/factory?*
        - *What is your role in the manufacturing process?*

Notes:

- Go over planning of interview:
    1) Intro + demo application
    2) TAM questionnaire
    3) Open questions / discussion
- Practicalities:
    - Can I record it?
    - Test the screen take over

Part 1: Explanation + demo of application

- Research is (partly) a continuation of Melanie’s project.
- Research regarding job quality, and guidelines which can be supported by BPMS software to maintain the quality of work.
- In this use case at TRI: try to support the physical load limits.
- Proof-of-concept uitleggen: extension was created on Camunda, this gives warnings to people and kicks them off tasks when the limits are reached. It is a proof-of-concept, not ready tob e implemented, more research/design is needed.
- I understood at this process you change workers every two hours, this system would do that automatically.
- Explaining the application:
    - Show Camunda modeler and how to use it.
    - Explain what the physical load input parameters mean (standing for instance means a standing task, not walking). Right now they are in seconds for testing/demonstration purposes.
- Demo: Let Ruud use Camunda modeler (watch what his input is):

- Demo: Run java application with Ruuds input, go through scenario.

Part 2: Usefulness evaluation (TAM questions)

The application = BPMS software which allocates tasks in a similar way as the demo does, based on self-declared physical strain characteristics and limits.

Goal = monitor and control the level of physical strain among the employees.

Perceived Ease-of-Use (PEU)

Notes:

1. *Learning how to use this application was easy for me.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

2. *I find it easy to let the application do what I want it to do.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

3. *My interaction with the application is clear and comprehensible.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

4. *I find the application flexible to communicate with.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

5. *It is easy for me to become competent in using this application.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

6. *I find the application easy to use.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

Perceived Usefulness (PU)

Notes:

7. *By using the application, monitoring and controlling the level of physical load experienced by the employees would* ***take less time.***

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

8. *Using the application would* ***increase my work performance*** *regarding monitoring and controlling the level of physical load experienced by the employees.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

9. *Using this application would* ***increase the extent*** *to which I monitor and control the level of physical load experienced by the employees.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

10. *By using the application, I would be* ***more effective*** *in monitoring and controlling the level of physical load experienced by the employees.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

11. *Using the application would make it* ***easier*** *to monitor and control the level of physical load experienced by the employees.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

12. *I think the application is* ***useful*** *to monitor the level of physical load experienced by the employees.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ● **Completely agree**

Perceived Usefulness (PU)

Notes:

13. Assuming I have access to the application, I plan on using it.

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ● **Completely agree**

14. Assuming I have access to the application, I predict that I would use it.

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ● **Completely agree**

Part 3: open questions

1. *Is currently any BPMS software used in the factory? Or are BPMN process models supported in the current systems?*

2. *Can you explain how you currently take physical load limits into account in the manufacturing process?*

3. *How much work is it currently for you or a manager or team leader to keep track of the time that employees spend in physically straining tasks? And to react to this?*

4. *Do you think this kind of support would lower your workload as a manager?*

5. *Do you think task rotation would increase in this way considering physically straining tasks?*

6. *How do you think that other factors would be influenced by this kind of implementation in the process? For example, would the throughput time increase a lot?*

7. *Would the employees in the process be happy with this kind of application? Or would they be annoyed by the warnings and forced task rotation?*

8. *Do you have any questions and/or remarks regarding the application? What are its strengths and weaknesses?*

Appendix J

Interview questionnaire for usability evaluation IMA use case (Q7b)

Use Case Expert interview – Usability evaluation – Guideline 2, 3 & 4

Use case: IMA – food products packaging

Interviewee: Aijse de Vries

Start:

- Introduce ourselves:
    - Eva: graduating master BIS, due to Industry 4.0 combined with human factors I arrived at Rossini project.
    - Aijse:
        - What is your role in the Rossini project?
        - What is your role at TNO?

Notes:

- Planning interview:
    1) Explain graduation project: goal of the project, what I built.
    2) Demo: show how it works.
    3) Try-out: Aijse takes over screen and gets to try it himself.
    4) TAM questionnaire
    5) Open/general questions regarding IMA and application.
- Practicalities
    - Can I record it?
    - Test screen takeover > otherwise skip to skype for business.

Part 1: Explain graduation project + demo & try-out

1) Explain graduation project
    a. Explain BPMN
    b. Explain BPMS
    c. Explain Camunda
2) Demo:
    a. Show process model and explain each step.
    b. Show how to claim and complete tasks in Camunda, show how machines sometimes fail, sometimes need maintenance.
    c. Show how autonomy and task variety functionalities are working.
3) Try-out:
    a. Restart application and three machines
    b. Aijse takes over screen, starts “working” as an employee at IMA

Part 2: TAM questions

The application = BPMS software which supports autonomy and task variety within the job of the employees, as shown by the demo.

Goal = Support autonomy and task variety in the job.

Perceived Ease-of-Use (PEU)

Notes:

1. *Learning how to use this application was easy for me.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

2. *I find it easy to let the application do what I want it to do.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

3. *My interaction with the application is clear and comprehensible.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

4. *I find the application flexible to communicate with.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

5. *It is easy for me to become competent in using this application.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

6. *I find the application easy to use.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

Perceived Usefulness (PU)

Notes:

7. *By using the application, supporting autonomy and task variety in the job would take* ***take less time.***

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

8. *Using the application would* ***increase the work performance*** *regarding supporting autonomy and task variety in the job.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

9. *Using this application would* ***increase the extent*** *to which autonomy and task variety in the job are supported.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

10. *By using the application, autonomy and task variety would be supported* ***more effectively*** *in the job.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

11. *Using the application would make it* ***easier*** *support autonomy and task variety in the job.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ○ **Completely agree**

12. *I think the application is* ***useful*** *to support autonomy and task variety in the job.*

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ● **Completely agree**

Intention to Use (IU)

Notes:

13. Assuming I have access to the application, I plan on using it.

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ● **Completely agree**

14. Assuming IMA has access to the application, I predict that they would use it.

○ **Completely disagree** ○ **Strongly disagree** ○ **Disagree** ○ **Neither agree, nor disagree** ○ **Agree** ○ **Strongly agree** ● **Completely agree**

Part 3: open questions

1. *Is BPMS software currently used at IMA? Or are BPMN process models used or supported by their current systems?*

2. *Currently, are autonomy and/or task variety taken into account in the process? Or are any other aspects of job quality taken into account?*

3. *Does it occur often that for instance all machines fail and need maintenance at the same time? If this happens, does the employee have the autonomy to react to this in a flexible manner? Or is he/she expected to solve everything as quickly as possible?*

4. *How do you think that other factors in the process would be influenced by such an application? Would for instance the throughput time increase a lot?*

5. *Would the employees working in this process be happy with such an application? Or would they not need it? Would they be annoyed by the warnings and forced breaks / task rotation?*

6. *Do you have any questions and/or remarks regarding the application? What are its strengths and weaknesses?*