Becoming smarter

A study into Industry 4.0 and its job design effects

Milou Habraken

BECOMING SMARTER

A STUDY INTO INDUSTRY 4.0 AND ITS JOB DESIGN EFFECTS

Milou Maria Petronella Habraken

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DISSERTATION

to obtain
the degree of doctor at the University of Twente,
on the authority of the rector magnificus,
Prof. dr. T.T.M. Palstra,
on account of the decision of the Doctorate Board,
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By

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born on the 3rd of April 1989
in Valkenswaard, the Netherlands

This dissertation has been approved by:

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ADDITIONAL INSERT

In my dissertation, I opted to address the two research questions alternatingly instead of following a content logic. An approach that was chosen due to the role played by temporality in the research. A factor that, due to the coronavirus, now also plays a prominent role in the completion of my PhD via a shift in the defence date,

Wednesday the 14th of October 2020 at 14.45 hours

And changes to Ch.5, as an improved version has been published.
Habraken, M., & Bondarouk, T. (2020). Embracing variety in decision-making regarding adoption of Industry 4.0. Administrative Sciences, 10(2), 30.

In addition, the virus may and might already have brought about changes, whether temporary or lasting, to the importance of, or decisions made with respect to Industry 4.0.

One thing, however, will remain constant no matter what.
The gratitude expressed in my acknowledgment!

ADDITIONAL INSERT

Time has also brought updates to the doctoral regulations. To ensure the chapters can sufficiently be attributed to the PhD candidate, it is now required to add a declaration of author contribution in the dissertation.

Chapter	**Author contribution**
1. Introduction	Milou Habraken outlined and wrote this chapter and made alterations based on feedback received from Prof. dr. T. Bondarouk, Dr. A.C. Bos-Nehles and Dr. J. de Leede
2. Smart Industry research in the field of HRM	Milou Habraken initiated and outlined this chapter, led the writing process and made alterations based on feedback received from the co-author, Prof. dr. T. Bondarouk, and from Dr. A.C. Bos-Nehles
3. Smart Industry or smart bubbles?	Milou Habraken initiated and outlined this chapter, collected and analysed the data, led the writing process and made alterations based on feedback received from the co-author, Prof. dr. T. Bondarouk
4. Shaking up the status quo?	Milou Habraken initiated and outlined this chapter, analysed the data, led the writing process and made alterations based on feedback received from the second author, Prof. dr. T. Bondarouk. Data was collected by the third author, D. Hoffmann, MSc
5. Using a decision making lens towards the application of Industry 4.0	Milou Habraken initiated and outlined this chapter, collected and analysed the data, led the writing process and made alterations based on feedback received from the co-author, Prof. dr. T. Bondarouk
6. Discussion	Milou Habraken outlined and wrote this chapter and made alterations based on feedback received from Prof. dr. T. Bondarouk

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- Tanya and Anna, my promotor and co-supervisor, who kick-started my PhD and guided me to the finish line. But you have also been so much more than a promoter and co-supervisor to me
- My graduation committee, prof. dr. Barbara Imperatori, prof. dr. Janet Marler, prof. dr. Michael Wasserman, prof. dr. Holger Schiele, and prof. dr. Jos van Hillegersberg. Some with whom I have had the pleasure of sharing the warmth and openness that is the e-HRM community. Though all, including my paranymphs Maarten and Rianne, help make the unforgettable finishing point a reality
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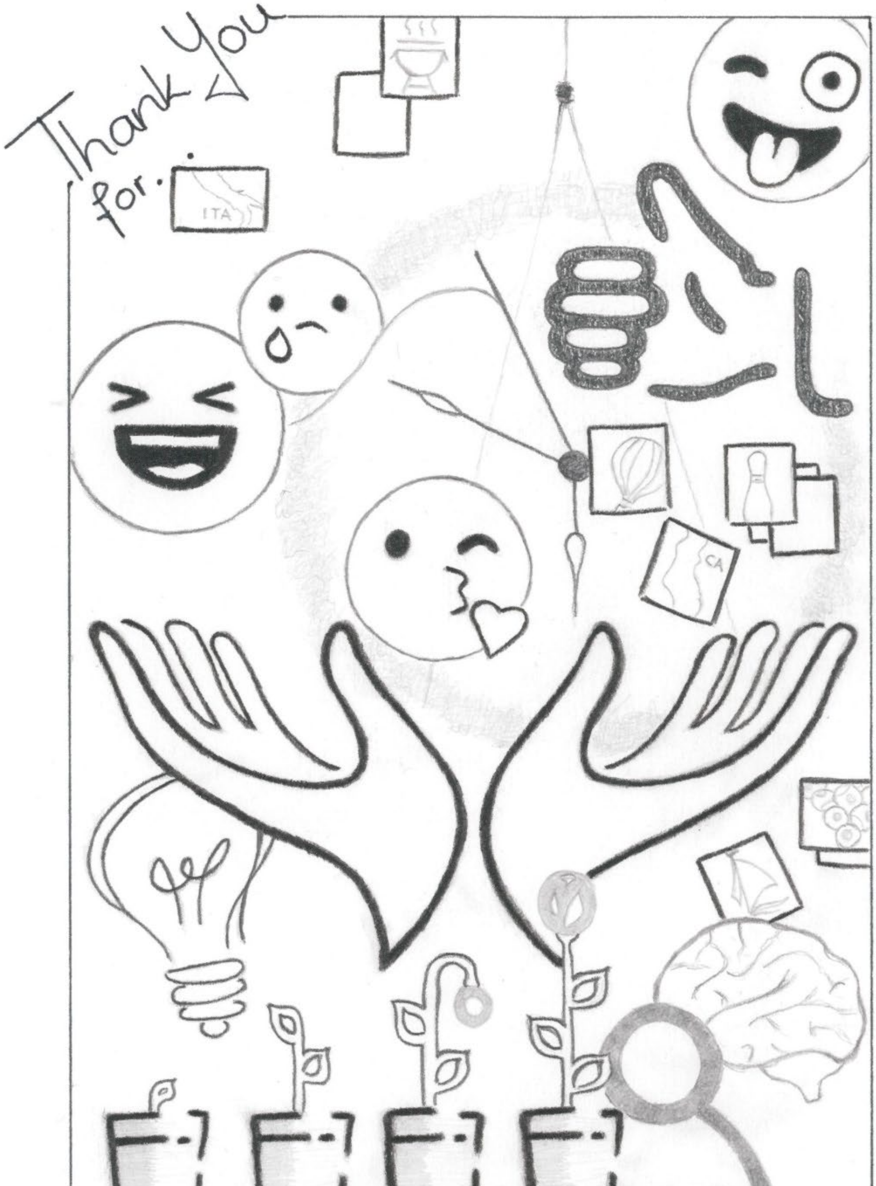
- The colleagues and friends that accompanied me on my PhD experience, for the journey would not have been the same without: the old and current members of the HRM group; fellow and former PhDs in the HBE cluster, PhDs visiting the HRM department and those met during conferences, or events; as well as scholars from the HBE cluster and members of the Dutch HRM and e-HRM community
- And finally, my (extended) family that is dear to me: ons mam, pap, broer, zus en Coby & Wim.

Though there is much to say, I will not be using words to show my gratitude. Instead, I am expressing myself, framing all that you have given me over the past years, in a different art form.

Milou – January 2020


Thank You
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CHAPTER 1

Introduction

1.1 Prologue, or getting acquainted

The number or amount of…

Published "Industry 4.0" documents; in respectively Web of Sciences and Scopus:
0 papers in 2011 to 1008 papers in 2018 – 0 papers in 2011 to 2007 papers in 2018

Worldwide search interest on Industry 4.0; based on Google trends:
On a scale from 0 to 100, Industry 4.0 reached <1 on Jan. 2011 and 100 on Feb. 2019

Conferences related to Industry 4.0; Liao, Deschamps, Loures, and Ramos (2017):
5 conferences in 2013 to 63 conferences in 2015

Consultancy interest; based on an Industry 4.0 search on respective websites:
Top 9 most prestigious consulting firms in 2018 (Vault.com) focus on Industry 4.0

Financed Smart Industry related NWO[1]-projects:
1 funded NWO-project in 2016 to 17 funded NWO-projects in 2018

As the above numbers show, the popularity or interest surrounding Industry 4.0 has grown rapidly in recent years. It has developed from a non-existent term to a phenomenon that has embedded itself on a global scale. The creation and evolvement of Industry 4.0, reflected in the numbers displayed above, has not only led to the establishment of the dissertation that lies before you it, in addition, has contributed to the rather unique process of this PhD project. In other words, besides Industry 4.0 being the main theme of this dissertation, it has also been the case that its emergence ran parallel to the PhD trajectory presented here. A circumstance that does not occur often. As a result, the temporal environment surrounding the subprojects in this dissertation influenced, more than usual, the type and order of the projects included. For instance, as time passed the trigger for the goal of the first paper reduced (i.e. alongside the growth of Industry 4.0's 'maturity', so did, albeit more slowly, attention to its social affects). Moreover, the development of the phenomenon over time led to the unveiling of issues and opportunities for reflection. The concept of time therefore plays an essential role in the structure of this dissertation (a detailed discussion of the structure is provided in Section 1.4).

[1] NWO is the Netherlands Organisation for Scientific Research

The research in this dissertation further contains two shifts: a change in the adopted label and a slight change in how I view Industry 4.0. To help understand these shifts, the variety in existing labels and the transition from Smart Industry to Industry 4.0 (1.1.1) as well as a content-related outline of the phenomenon (1.1.2) are discussed next. This section concludes with a link to practice, with Subsection 1.1.3 offering examples of how Industry 4.0 is shaped in practice.

1.1.1 A bunch of labels and the made transition

The origin of the phenomenon derives from the German term Industrie 4.0 which constitutes an eponymous initiative that promoted the label as a means to strengthen the competitiveness of the German manufacturing sector. Advocates of this initiative portrayed Industrie 4.0 as having huge potentials for manufacturing industries (such as creating dynamic business and engineering processes, meeting individual customer requirements, and facilitating optimised decision-making) and solving broader challenges like demographic change and resource efficiency (Kagermann, Wahlster, & Helbig, 2013). The initiative, and thus the term Industrie 4.0, entered the public consciousness when it was mentioned at the Hannover Messe industrial trade fair in 2011 (Pfeiffer, 2017). After this trade fair, the vision behind Industrie 4.0 spread to other countries. As of June 2017, fifteen national initiatives for digitising industry were active in Europe (EuropeanCommision, 2017) and similar ideas can also be found in global initiatives such as 'Made in China 2025', 'Make in India' or 'Advanced Manufacturing' in the USA (Petrillo, de Felice, Cioffi, & Zomparelli, 2018). Most of the European initiatives adopted the German Industrie 4.0 label or its English translation – Industry 4.0. Nevertheless, several countries use a different label. In other words, not only has the label Industry 4.0 been added to the mix, the addition of unique labels creates an even greater variety. One such unique label is the term Smart Industry used in the Netherlands, as can be demonstrated with the following statements from respondents in our study described later (Chapter 3): '*You should not bring a German term like Industrie 4.0 to the Netherlands. We don't really like German labels, it must always sound a bit English, and if you give it an original name it seems as if you invented something new. As if you invented it yourself. Then of course it is very smart to call it Smart Industry*' and '*We are going to approach technology, something like Industry 4.0,* *more business driven, at least we tried and we named it Smart Industry*'. To summarise, the presence of labels such as Industry 4.0 and Smart Industry, and likely many of the other varieties, stems from the fact that countries decided to use a literal English translation or created their own label for the vision that arose in Germany (i.e. Industrie 4.0).

The question that remains is whether treating the terms as equivalents is justified? With respect to Industrie 4.0 and Industry 4.0, both labels are often considered to be identical. The fact that one is a literal translation of the other supports this notion. Consequently, their interchangeability is tacitly assumed. The transition visible in this dissertation, from Smart Industry to Industry 4.0, is based on findings from the study described in Chapter 3. Results show that Industry 4.0 and Smart Industry, as understood in the Netherlands, can be used interchangeably. After this study, my initial adoption of the term Smart Industry (due to the embeddedness of the project in a Dutch University) was replaced by Industry 4.0. One reason for this shift is the existing prevalence of Industry 4.0 in academia (for more details see Chapter 3).

1.1.2 The content of Industry 4.0

Providing a description of Industry 4.0 is not a straightforward task since, to date, a generally accepted understanding of the phenomenon does not exist. In addition, the multiple contributions from academia and practice, as a result of its popularity, are counterproductive with respect to obtaining a unified meaning. Examples of the way in which the phenomenon is described on websites of several European national initiatives are provided in Table 1.1.

Table 1.1 Definitions from various European national initiatives (as of April 2019)

Country & Platform	Definition & Source
AUSTRIA Industrie 4.0 Österreich	"Industry 4.0 is defined as the digitalization and integration of the entire value chain and follows the mechanization, electrification and automation as the fourth industrial revolution. The change is taking place at all stages of the production process (value chain). Industry 4.0 refers to both upstream and downstream integration such as suppliers or logistics company as well as internal corporate processes such as procurement, production, sales and maintenance. Therefore Industry 4.0 leads to higher productivity and flexibility, more innovation and resource preservation" http://plattformindustrie40.at/was-ist-industrie-4-0/?lang=en

BELGIUM Made Different – Factories of the future	“Factories of the future 4.0 are forward-looking manufactures who systematically take up the challenges of the fourth industrial revolution. They supply products with high value added and are flexible enough to respond to swiftly changing market demand. This also enables them to continue playing a major role in a dynamic worldwide manufacturing network” http://www.madedifferent.be/en/services
DENMARK Manufacturing Academy of Denmark (MADE)	“Industry 4.0 has ushered in a new era for Danish industry. It’s about creating business possibilities, jobs, better connections and new ways of thinking about production” https://en.made.dk/about-made/ *> see video*
GERMANY Industrie 4.0	“Industrie 4.0 refers to the intelligent networking of machines and processes for industry with the help of information and communication technology” https://www.plattform-i40.de/PI40/Navigation/EN/Industrie40/WhatIsIndustrie40/what-is-industrie40.html
HUNGARY IPAR4.0 National Technology Initiative	“The term Industrie 4.0 stands for the fourth industrial revolution based on cyber-physical systems, i.e. the formerly never seen integration of the physical and virtual worlds, and represents a new level of organising and controlling the entire value chain across product lifecycles. This cycle focusses on increasingly personalised customer wishes and extends from the concept to the order, development, production, and shipping of a product to the end customer and ultimately to its recycling, including all associated services. The foundation is the real-time availability of all relevant information through the integration of all objects in the value chain and the capacity to determine the optimal value flow at any time from the data. The interconnection of people, objects, and systems produces dynamic, real-time-optimised, self-organising, cross-enterprise value-adding networks that can be optimised according to various criteria such as cost, availability, and resource consumption” https://www.i40platform.hu/en/about_us *> see definition document*
PORTUGAL Indústria 4.0	“There is a paradigm shift in industry – in fact, across the economy. A Fourth Industrial Revolution is under way and will bring in digital technologies across all industries. … That is why we have developed a strategy for digitizing our economy, and especially the industry – we call it Industry 4.0. This is not a digital strategy. It is the strategy for our country’s competitiveness in a digital world” (detailed content only available in Portuguese) https://www.industria4-0.cotec.pt/en/about/
SWEDEN Smart Industry	“Innovative and sustainable industrial production is digitally connected, flexible, resource-efficient, environmentally friendly and provides the conditions for an attractive workplace. This Smart Industry is at the forefront of the digital transformation, has a high level of automation and is well equipped to meet complex customer requirements and new patterns of demand. It competes using both advanced production and products with a high knowledge content, where the boundary between goods and services has been blurred and where huge volumes of data create new assets for both customer and supplier” https://www.government.se/information-material/2016/04/smart-industry---a-strategy-for-new-industrialisation-for-sweden/ *> see Smart Industry document , p.24*

Moreover, the ways in which Smart Industry has been communicated over time by the Dutch national platform highlights that even a single source in a single country has not yet achieved a stable interpretation. Table 1.2 shows, for instance, that information was a driver in 2014 but then disappeared. Digitisation/ICT, networks/connectivity and new technologies, which were seen as drivers in 2014 and 2018, were presented as core characteristics in 2017, with the driver that year being the 'smart use of IT'. What is also striking is that a vision is mentioned in the definitions of 2014 and 2018 but not included in 2017 and 2019. In addition, the 20108 definition is the only one not to address any outcome aspects. In the other three, the outcome aspects are not consistent. Ranging from being fully oriented towards the production process to including products and even new sectors.

Table 1.2 A sample of Dutch Smart Industry definitions over time

Source	Definition	Summary
(Huizinga et al., **2014**, p. 25)	"We define Smart Industry as follows, to be seen as a **strategic vision** of our future industry: Smart Industries are... industries **that have** a high degree of flexibility in production, in terms of product needs (specifications, quality, design), volume (what is needed), timing (when it is needed), resource efficiency and cost (what is required), being able to (fine)tune to customer needs and make use of the entire supply chain for value creation. It is **enabled by** a network-centric approach, making use of the value of information, driven by ICT and the latest available proven manufacturing techniques"	- 1 vision - various outcomes - 4 drivers
Promotion material first Smart Industry year event on February **2017**	"Smart Industry is **driven by** the smart use of IT, which means that machines are interconnected and can be controlled smartly. Not only within the factory, but also between companies themselves and between companies and customers. **It is all about** a combination of the use of production technology, digitization and a network approach. **And it is about** smart products, processes and services"	- 1 driver - 3 core characteristics - 3 outcome groups
(Ahsmann et al., **2018**, p. 9)	"Smart Industry **is about** future-proof industrial & product systems; these are smart and interconnected and make use of Cyber Physical Systems. Digitization, connectivity and new manufacturing & product technology **are drivers** for this"	- 1 vision - 3 drivers
(Teamsmartindustry, n.d.) accessed on April **2019**	"Smart Industry **is the** far-reaching digitization and interweaving of devices, means of production and organizations. **This creates** new ways of production, business models and sectors"	- 2 core characteristics - 3 outcome groups

Given the above information, the slight change in how I view Industry 4.0 should be considered a result of its evolvement over time. With time, more knowledge and reflection opportunities became available leading to new viewpoints or my perspective, on Industry 4.0. This perspective, described below and presented in more detail in Chapter 3, is not intended as yet another definition. Rather, the aim was to show that there is coherency within the apparent chaos of definitions. Although I do not claim it to be *the* description of Industry 4.0, it hopefully helps to bring a more generally accepted understanding of the phenomenon a step closer.

Based on the data from the study within Chapter 3, two distinct components were created to represent the phenomenon: a communicative bubble and a platform for the multiplicity and complexity of current developments. The first component depicts the intentions behind the label which are: retaining the competitiveness of manufacturing industry and, related to this, building awareness and accelerating existing technological developments. These intentions, in turn, explain the expected outcomes (e.g. increased flexibility or enhanced customer interaction) that accompany Industry 4.0. They promote the developments and, in so doing, help ensure the stated intentions are achieved. The second component expresses the three technology-based developmental streams that currently exist: connected, informed and equipped. In more detail, these have been expressed as: "(1) the establishment of connections between devices and/or systems within firms and with external parties worldwide, (2) the ability to take more advantage of the value of information via the presence of greater amounts of data, and (3) the availability of contemporary physical and non-physical assets" (Habraken & Bondarouk, 2019, p. 13). In contrast to several of the definitions highlighted in the tables above, digitisation is not included as a fourth technology-based developmental stream. Although this aspect was visible in the data, it is not considered a separate stream because its content is embedded within the other three elements – "the emerging connections imply a digital format, the value in information becomes a critical factor because of the large quantities of information available as a result of data which has been transformed or is natively digital, and assets such as augmented reality require a digital component in order to function" (Habraken & Bondarouk, 2019, p. 13). As a result, digitisation is considered redundant as a stand-alone category.

Finally, the platform component incorporates the fact that the application of these streams is restricted by social and IT-related constrains (e.g. required supporting infrastructure or privacy issues).

1.1.3 Insights from practice – some examples

This subsection offers an impression of the manner in which Industry 4.0 is shaped within practice, but is by no means an exhaustive list. Industry 4.0 is complex and the possibilities it creates are diverse (and potentially still unknown since the phenomenon is surrounded with considerable exploration). It should thus be kept in mind that the presented examples are indicative of the way Industry 4.0 has been shaped by just four organisations. Data from these four cases stem from organisations that are referred to as examples of smart companies by the Dutch national and a regional platform for this phenomenon. These data were collected as part of the study discussed in Chapter 5. As a result, the included references are presented in Appendix D that is part of that chapter.

- Bruil: Concrete factory with approximately 400 employees

The main Industry 4.0 direction highlighted for Bruil is the 3D technology that has been introduced for printing concrete. In other words, this organisation self-developed a 3D concrete printer. In addition, the organisation has had software created to convert the 3D models supplied by the architects into print paths for the printer. The following quote also offers a brief insight into other developments that are changing this branch: “now that our production processes are becoming smarter by making full use of smart digital applications, we can also make our product itself smarter. Smart concrete indeed. It is already possible to incorporate, within concrete, sensors that measure and control the temperature in homes or business spaces. It is just one example of how Smart Technology is going to change our industry enormously” (Boost_B, 2017).

- De Cromvoirtse: Supplier of sheet metal with approximately 60 employees

Industry 4.0 is visible here in the people-light order to production chain, hence they have automated the entire process from quotation request to production. The organisation has an automatic calculation and quotation system, a fully automated warehouse with 900 pallet places and machines (e.g. welding robot) that operate automatically and where the changeover time is zero. More importantly, many of these aspects, or rather the IT systems behind them, are connected – "to do this [automatisation], you must be able to recognise a customer's drawing, convert it into a quotation using software, then automatically have the right materials moved from the warehouse, have it processed, packaged, etc." *and* "the biggest bottleneck was, and is, linking the IT systems together. Consider our web portal, our ERP system and process automation" (Van Ede, 2015). It thus involves considerable 'communication' and smart resources to realise the process that this organisation has achieved. This also comes across in the following quotes regarding their warehouse: "supply and removal takes place with robot cars. Not only must the correct plates be collected automatically, residues must then be stored again for later use" (Van Ede, 2015) *and* "the remnants that remain are recognised and stored. The moment material is cut again, it is checked whether the stored material can be re-used" (National platform_DC, n.d.).

- House of Blue Jeans: Clothing store, number of employees unknown

In this organisation, Industry 4.0 is shaped by the facts that it accepts payments in DigitByte and the following scenarios are in use: 1. "when you place a piece of clothing on the wooden box next to the full-length mirror, 360-degree photos automatically appear on the mirror"; 2. "by moving your finger over the photo, you can rotate the article virtually and view it from all sides. And you immediately get combination suggestions"; 3. "thanks to iBeacons, the system already knows who is in the fitting room, as long as the customer has downloaded the app on his smartphone. There is a screen in the fitting room on which the photos of the item of clothing appear as soon as you hang it on the wall. The screen offers more options, so you can ask the seller to bring a different size and you can already pay for your purchases. If you put a pile of clothing on the counter, the total amount will appear on the counter within two seconds" (National platform_HBJ, n.d.).

- Kornelis Caps & Closures: Producer of caps and closures primarily for food products with approximately 60 employees

The Industry 4.0 transition for this organisation centres around the constant monitoring, analysing and controlling of production data. In their newly built factory, they will gather data on just about anything: "a smart factory with machines that are full of sensors that measure productivity. They keep track of everything: process values, alarms, vision control images, temperature, humidity, energy consumption, outages, malfunctions, logs, checklists, etc" (Verpakkings management, 2017). Data which can be read out via an app. An essential remark made with respect to the collection of data is the following: "collecting data is not that difficult, but actually doing something with it is in our opinion Smart Industry" (Boost_KCC, 2018). Besides the gathering of data, the new factory will also contain intelligent, connected features as is evident in the next quote: "the idea that customers will soon enter their own orders and that the machines themselves will then come up with the most ideal production sequence ensures that we can use both new and existing machines even better" (Boost_KCC, 2018). Finally, after the completion of their smart factory, the firm intends to build a new warehouse. "We are going to automate the packaging and in the future AGVs [automated guided vehicles] will automatically transport the boxes of finished products to the, still to be built, warehouse" (Verpakkings management, 2017).

The above examples show that the manner in which Industry 4.0 is shaped in practice ranges from the use of resources such as 3D printers, AGVs, virtual imaging and apps; the adoption of digital forms of payment; intelligent and connected systems/machines within an organisation; as well as the collection and relevant use of data. Together, they highlight the complexity and diversity surrounding Industry 4.0, as is also reflected in the various labels and the variety in the content descriptions presented in the previous subsections.

1.2 Back in time – societal pressures and the research motive

In 2015, during the initiation and start of this project, the Dutch Smart Industry label was largely uncharted territory since the first report that addressed Smart Industry in the Netherlands was not presented until April 2014 (Huizinga et al., 2014). The label Industrie 4.0, announced in 2011, had, by then, been around for approximately four years. Yet the final report from the German Industrie 4.0 working group was only published in April 2013 (Kagermann et al., 2013). Figure 1.1 shows that academic and public interest in Industrie 4.0, as well as Industry 4.0, did not really take off until 2014-2015. As such, the phenomenon could still be considered a relatively new field in 2015. This fact was especially true in terms of taking a social perspective towards Industry 4.0. That is, what had been published by then mostly explored the concept from a technical point of view (Vacek, 2016). The Dutch Fieldlabs that existed at the end of 2015 offer a similar perspective since their focus was very technology-driven (e.g. robotic knowledge, connecting ICT systems, digitising processes).

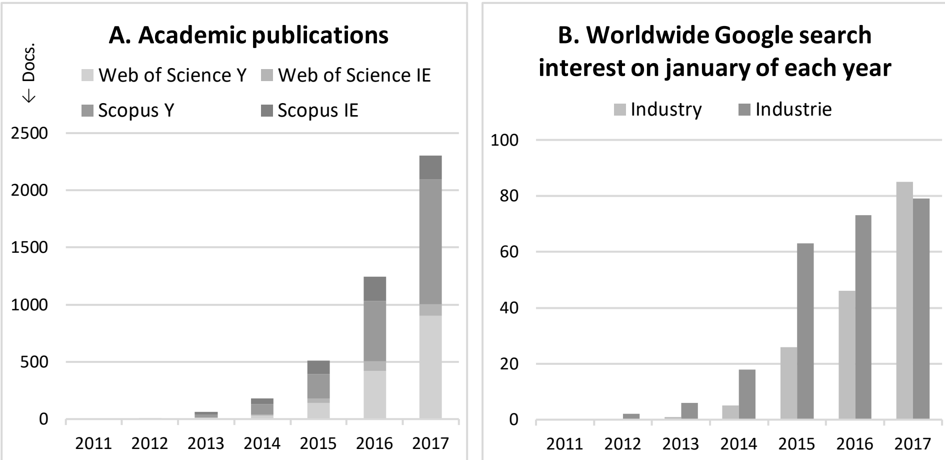

Figure 1.1 Amount of attention to Industr**y**- and Industr**ie** 4.0 in academia / practice
Note: The result for a Google search interest query is presented on a scale from 0 to 100. A score of 0 implies insufficient data and a value of 100 is peak popularity.

Despite its novelty, there were signs that this phenomenon would become a huge and important topic for the social sciences. A first sign was its notation as the fourth industrial revolution. After the advancement of water/steam power, electrical power and electronics/computers, Industry 4.0 was highlighted as being another disruptive leap in the industrial process. Something framed as a rapid major change in an economy (i.e. industrial revolution; according to the Merriam-Webster dictionary) will be inextricably linked with social issues. A second signal originated from the paper by Frey and Osborne (2013, p. 3) which addressed the issue of “what recent technological progress is likely to mean for the future of employment”. Their finding that 47% of total US employment was estimated to be at risk for computerisation sparked a discussion on the possibility of massive unemployment, despite the fact that the paper was not published in a peer-refereed journal. Examples in which this debate played a central role include a report from the Rathenau institute[2] entitled '*Working on the robot society: Visions and insights from science about the relationship between technology and employment*' (2015); an opinion piece in Tijdschrift voor Arbeidsvraagstukken[3] entitled '*Robotization: It is possible, but is it necessary?*' (2015); and a research report by Deloitte entitled '*The impact of automation on the Dutch labour market: A thorough exploration based on data analytics*' (2014)[4]. Thirdly, a frequently raised question was what skills would be needed in an Industry 4.0 context? In other words, it was assumed that the skills necessary were subject to change. The official Dutch report on Smart Industry, in 2014, for example stressed that "it is to be expected that the disciplines, expertise and knowledge of today will not be sufficient for the Smart Industry worker of tomorrow" (Huizinga et al., 2014, p. 35). On top of that, various authors offered expectations with respect to which skills would become essential – skills in the areas of ICT, communication, problem-solving and creativity were for instance highlighted as being likely to increase in importance (Berger & Frey, 2015; Levy & Murnane, 2013; Ten Have, Van Rhijn, & Van Wijk, 2014). Although the content of these reports mainly concerned expectations, they revealed the potential of Industry 4.0 to cause shifts in the social domain and, in so doing, highlighted the need to consider Industry 4.0 from a social perspective. A final sign, that contributed to the realisation that this phenomenon would become a social matter to be taken seriously, was a speech about the robotisation of labour given by the Minister of the Dutch Ministry of Social Affairs and Employment (i.e. Lodewijk Asscher) in September 2014[5]. For a minister responsible for work and social security to become involved in a subject, it must mean it has a certain level of importance. In his speech, the minister addressed that the fight against unemployment was not only a short-term priority. He pointed out that, with the rapid rise of robots and other technology, the future could look drastically different. The speech continued with several examples of how technological developments can affect the labour

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[2] A knowledge institute; https://www.rathenau.nl/nl/digitale-samenleving/werken-aan-de-robotsamenleving
[3] A scientific magazine adopting a social science perspective; https://www.researchgate.net/publication/282210594_Robotisering_het_kan_maar_moet_het_ook
[4] https://www2.deloitte.com/nl/nl/pages/data-analytics/articles/mogelijk-2-3-miljoen-banen-tocht.html
[5] Access speech via: https://www.arbeidsdeskundigen.nl/dossiers/robotisering/presentaties/document/akc/1252

market and a scenario of what it would mean if robots led to technological unemployment. This scenario was followed by the statement that, so far, the technological development had not resulted in higher unemployment but did show itself in lower remuneration for employees, a more lopsided distribution of income and less income security. The speech then moved on to the question of what this meant for Dutch policy, which was approached from education, employer and employee perspectives. Lodewijk Asscher ended his speech with the conclusion that, in the long term, there were big policy questions as well as enormous changes ahead for employers, employees and society as a whole.

In short, back in 2015 when the research proposal for this PhD project was written, Industry 4.0 was a concept that had just started to gain academic and practical attention. Despite the direction of this attention being primarily technical in nature, there were signs pointing towards the impact the phenomenon could have with respect to work and more broadly the field of human resource management (HRM). This showed the subtle presence of social issues surrounding Industry 4.0. These social issues, combined with the growing interest from technical research fields, led to the assumption that Industry 4.0 would become noteworthy and require a huge effort by scientists from different disciplines, among which HRM scholars. This belief gave rise to this dissertation. In other words, the assumption stated above triggered the notion that Industry 4.0 had the potential to be a unique but relevant opportunity to, knowledge-wise, run alongside a rising phenomenon. An opportunity with as motive to build an Industry 4.0 HRM-related knowledge base from which to offer practical support and expand academically as the phenomenon evolved further.

1.3 Not one, but two related main research questions

The formulated research motive – to build an Industry 4.0 HRM-related knowledge base – might suggest different intentions. With a solid Industry 4.0 concept it could, for instance, imply building a knowledge base with respect to its consequences for the field of HRM. Yet, as already stated, Industry 4.0 emerged in parallel with the PhD trajectory presented here and, as the phenomenon evolved, it unveiled issues and opportunities for reflection. In other words, it was found to be anything but solid and clear. Over time, the need to adopt a more critical view towards the phenomenon became apparent in order to improve our comprehension of the phenomenon and strengthen the concept. As a result, this dissertation has not one but two aims. One is focused on the Industry 4.0 phenomenon itself and the aim here is to obtain a better understanding of the phenomenon. The second aim is to explore the manner in which Industry 4.0 influences human resource management and hence it addresses the implications of the phenomenon. Given the immense scope of the HRM field, some demarcation was necessary resulting in a focus on job design – “the content and organization of one’s work tasks, activities, relationships and responsibilities” (Parker, 2014, p. 662). Given the number other options (e.g. the role of managers, HR practices, employees perceptions, or obtaining more concrete evidence regarding the necessary skillset), limiting the research to a single topic may seem constraining. However, the need to narrow the scope was a consequence of the aforementioned aim. Before turning to the research questions that arise from these aims, the focus on job design is justified. This direction was chosen because:

- It fits within employment debate as, by disagreeing with a jobless future (see Chapter 2) issues concerning the (re)arrangement of work logically follow. In other words, technological developments do not dictate the design of work but they are considered to be a main contextual factor influencing job characteristics (Morgeson, Garza, & Campion, 2012)
- It extends the observed discussion on skills through the inclusion of task, social, and contextual aspects of work in addition to knowledge elements
- Job characteristics have been found to correlate with various important outcomes – attitudinal, behavioural, cognitive, and well-being outcomes (Humphrey et al., 2007)
- It is linked to an extensive body of research yielding a rich amount of theoretical background to contribute to the provision of a theoretical basis.

To conclude, the projects carried out in this dissertation cover two related **main research questions**: 1) *‘What does the Industry 4.0 phenomenon entail?’* and 2) *‘In what way does Industry 4.0 affect job design?’*

1.4 Overview of research challenges and subprojects

The research motive behind this dissertation was to build an Industry 4.0 HRM-related knowledge base from which to offer support and expand it as the phenomenon continued to evolve. This motive is reflected and concretised in the two formulated research questions or adopted focus areas: (1) Industry 4.0 itself and (2) the effect of Industry 4.0 on HRM, specifically on job design. A key element within the stated motive is the word 'build' since, in contrast to actions like enhance or advance, it underscores the newness of the Industry 4.0 label at the start of this dissertation. This was true for the phenomenon in general but, given the primary technical viewpoint that was initially adopted (Vacek, 2016), Industry 4.0 was certainly a novel concept in the human resource management research field back in 2015-2016. It is with this issue that I start the discussion on the research challenges and subprojects that form this dissertation (see also Table 1.3 at the end of this section).

Time box 1:

A quick glance at the table of contents, reveals that the chapters do not follow a content logic. Such an approach would have involved presenting projects dedicated to one research question, and then projects dedicated to another. Instead, I have opted to take an interwoven approach, where the two research questions are addressed alternatingly. This approach was chosen due to the role that temporality plays in the research. To point out the temporal nature, a time box has been added at the start of chapters 2 to 5.

1.4.1 Existing research into Industry 4.0 excludes an HRM viewpoint ... why?

By now it should be clear that, at the outset of this dissertation, Smart Industry, or Industry 4.0, was an emerging phenomenon that was expected to rapidly receive more attention. Contributors to this latter fact include the denotation of a fourth industrial revolution, the many positive outcomes being attributed to the phenomenon as well as statements such as "Smart Industry is the future" (Huizinga et al., 2014, p. 5). Academic interest could thus not fall behind. A fact that had been picked up by the technical sciences. The combination of the Web of Science categories of automation control systems (36.2%), engineering electrical electronic (20.7%) and computer science information systems (13.8%), for instance, represent 70.7% of the research output on Industry 4.0 between 2011 and 2015. In contrast, categories such as management or business represented respectively only 3.2% and 0.5% of the same research output. However, the social issues discussed earlier showed that the phenomenon not only required effort from the technical disciplines. Industry 4.0 also created research opportunities for the field of HRM. But these opportunities were not being taken up by related scholars and there was a lack of HRM-related research into the phenomenon. An obvious reason for this is the novelty of the phenomenon. On the other hand, the massive employment debate at that time might also have discouraged further research. That is, not only was it a hot topic that could have claimed all the attention, adopting a jobless future view would also make investing in HRM seem less urgent or relevant.

Study 1, therefore starts with an in-depth discussion, and our view, on the employment debate. More specifically, the perspective taken is not one of a jobless future and, as such, HRM remains a pertinent research domain. One that ought to follow the lead of the technical disciplines and consider inquiries into Smart Industry. Consequently, the study provides indications of issues that arise from Smart Industry, specifically using a job design lens. It combines the then existing understanding of the phenomenon with a self-constructed overview of existing research on job design to: explore the direct and moderating effects of Smart Industry on job characteristics and their respective outcome(s). In addition, it uses the phenomenon as a source of inspiration for a configurational approach. With this, the study aims to highlight the importance of raising questions and conducting research towards Smart Industry from a more social, or human resource management, perspective. The goal of this study is thus to *encourage and guide Smart Industry HRM-related research.* It does so by addressing upcoming challenges developed using a job design lens.

1.4.2 Meaning and value of Industry 4.0 related labels are unclear

The intention behind the subsequent study was to develop a 'firm smartness' scale. Such a tool was not only thought to enable insights into the progress of Industry 4.0, it would also aid the shift from conceptual to more empirical output (i.e. an analysis of the effect of 'firm smartness' on job characteristics). Investing effort into an assessment method, however, became futile due to growing concerns regarding the meaning of Industry 4.0. Firstly, the paper by Hermann, Pentek, and Otto (2016) pointed out the lack of a common or generally accepted understanding of the term Industry 4.0, which they tackled via the development of four design principles for Industry 4.0. Secondly, findings from our conversations with Dutch Smart Industry experts (held to establish relations for developing the 'firm smartness' assessment tool) showed that Smart Industry was more complex than its original definition suggested. In addition, as clear from Table 1.2, the February 2017 definition of the Dutch Smart Industry label differed to the one from 2014. These observations highlighted the need to analyse the phenomenon itself more thoroughly.

It seemed as if the content of Industry 4.0 had suffered from its sudden increase in popularity and, possibly, its background as promotion material. Therefore, it was essential to take a step back and examine the phenomenon more closely. By examining the meaning of the Dutch Smart Industry label more closely, the interchangeability of existing denotations of the fourth industrial revolution also became a prominent issue. Thus far, Smart Industry had been considered to be interchangeable with Industrie 4.0 or Industry 4.0. An assumption that was in line with statements indicating that Industry 4.0 overlapped with labels such as the Industrial Internet of Things, Smart/Advanced Manufacturing or Smart Industry (e.g. Davies, 2015). Yet, with confusion regarding the meaning of existing labels rising, hence being stated or addressed, the assumed interchangeability became a questionable matter. First, it became difficult to presume equivalence when the labels themselves are not clear. Secondly, a growth in academic output was not only observable for Industry 4.0, it was also apparent for the alternative labels (see Figure 1.2). So it seemed that either existing assumptions were incorrect or an excessive number of labels were being used in international publications. Given that the study by Hermann et al. (2016), adopted and published under the label Industrie 4.0 but incorporated Industry 4.0 within their literature selection, the emphasis seemed to be on the latter. To summarise, not only did a challenge arise regarding the meaning of Smart Industry, and other labels, the question also arose whether the use of these diverse labels in scientific research served an essential purpose.

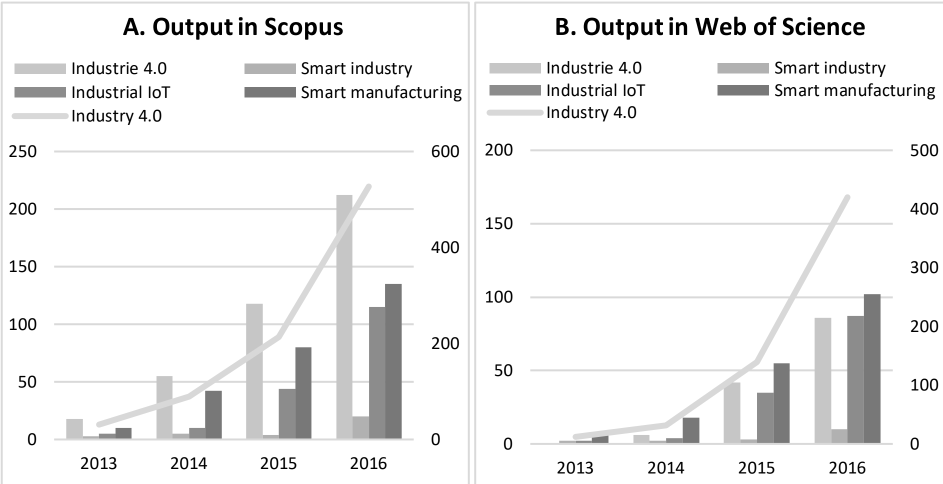

Figure 1.2 Research output (based on title, abstract and keywords) per label
Notes: Abbreviation IoT stands for Internet of Things; Right axe shows the line graph.

Consequently, study 2 addresses both issues by investigating whether the combining of labels could be extended beyond Industrie 4.0 and Industry 4.0. That is, the study adopts a focus on the Dutch Smart Industry label – creating a representation for this label and then comparing it to descriptions of the general term 'fourth industry revolution' and the Industry 4.0 label as developed by various scholars. In other words, it raises the question *what is the value of Smart Industry?* In so doing, the paper contributes new insights to the challenge of a lacking understanding of labels denoting the fourth industrial revolution, and offers an initial reflection on the necessity of the diversity in labels.

1.4.3 Research on the social context of work in Industry 4.0 is missing

Having addressed the concern that arose regarding the meaning and value of the Dutch Smart Industry label, a return to job design was made. Research on job characteristics related to Industry 4.0 typically focused on the content of job design. That is, the task and knowledge characteristics (i.e. those that either "are primarily concerned with how the work itself is accomplished and the range and nature of tasks associated with a particular job" or "reflect the kinds of knowledge, skill, and ability demands that are placed on an individual as a function of what is done on the job"; Morgeson and Humphrey (2006, p. 1323)). Examples of such research include: (1) the various papers that address the question of which jobs will remain; (2) the empirical study by Bosch (2016), that explores changes in core job characteristics[6] in the era of Smart Industry; (3) the papers by Parker and Zhang (2016) and Waschull, Bokhorst, and Wortmann (2017) that both express the expectation of an increase in knowledge demands due to the increasing digitalisation of work. In other words, they anticipate a greater need for information processing or jobs that entail more cognitive complex activities and challenging analytical, problem-solving, and decision-making tasks. In the following statement, Waschull et al. (2017, p. 279) also highlighted a potential change in a task-related factor: "manual work might be simplified and constrained as detailed and standardised digital work instructions can be provided that allow little room for deviation and job autonomy". Finally, (4) the massive interest that took off regarding the skills issue, including:

- Corporaal, Alons, and Vos (2015) > develop a skill profile for the technician of the future based on employers' expectations
- Hecklau, Galeitzke, Flachs, and Kohl (2016) > develop a competence model stemming from the identification of emerging challenges
- Grzybowska and Łupicka (2017) > explore the key managerial competencies through a literature review and a survey among experts in two industries
- Prifti, Knigge, Kienegger, and Krcmar (2017) > develop a competency model, for employees with higher education, via literature review and focus groups
- Hecklau, Orth, Kidschun, and Kohl (2017) > conduct a systematic review examining critical competences as depicted by well-known institutions.

In addition to this common focus on content, two papers were identified that suggested the presence of a focus on contextual characteristics which "reflect the context within which work is performed" (Morgeson & Humphrey, 2006, p. 1323). One, the paper by Parker and Zhang (2016), stressed that the increasing availability of technology has led to a visible shift from physically demanding occupations to more sedentary ones. As an example, consider the Kiva robots that can lift and move shelving units to human workers in warehouses (Brynjolfsson & McAfee, 2014). The other paper (Gašová, Gašo, & Štefánik,

[6] Core job characteristics are: skill variety, task identity, task significance, autonomy and feedback from the job

2017), touches upon the field of ergonomics in the context of Industry 4.0. Overall, three of the four distinct job characteristic categories seemed to have been picked up by scientists when considering Industry 4.0. Yet, to our best knowledge, the social category ("which reflect the fact that work is performed within a broader social environment"; Morgeson and Humphrey (2006, p. 1323)) remained unexplored. This seems remarkable given the following statements: "today, work design researchers are increasingly recognising that jobs, roles, tasks, and projects are embedded in interpersonal relationships, connections and interactions" (Grant & Parker, 2009, p. 323) and "these [i.e. social] dimensions, therefore, deserve greater attention from scholars than they have received heretofore" (Oldham & Hackman, 2010, p. 468). Furthermore, it would be unlikely for this domain to remain unaffected. For one, the often voiced assumption of achieving far-reaching supply chain cooperation already creates an expectation of change. To that end, study 3 aims to *analyse what developments can be observed with respect to the social context of work as a result of the Industry 4.0 work context.* It, thus, provides initial insights into the influence of Industry 4.0 on the social dimensions of work.

1.4.4 Existing discrepancy between Industry 4.0 commotion and application, combined with a dominant research focus on implementation

As reflected in the numbers at the start of this introduction and in Figure 1.1, the fascination for Industry 4.0 rapidly increased. Becoming a topic of interest among academia, companies, and politicians. It resulted in a proliferation of reports, academic publications, conferences, industry-related fairs, funding, as well as media attention focused on this phenomenon. This level of attention, or commotion, creates a certain expectation about the extent that Industry 4.0 is applied. Based on the findings presented in Chapter 4, and statements made in recent publications (Freese, Dekker, Kool, Dekker, & van Est, 2018; Huizinga et al., 2018), there seems to be a mismatch between the commotion and the realisation of Industry 4.0 in practice. Industry 4.0 is less prominent in practice compared to its written form. That is, the adoption of Industry 4.0 can be seen as lagging behind. This is a troubling notion considering that more and more emphasis is placed on comprehending the effects of this phenomenon. For instance, the knowledge agenda 2019-2022 from the Dutch Ministry of Social

Affairs and Employment (SZW) raised the following knowledge questions regarding the theme labour market and future of work: '*to what extent does the working day change as a result of technological developments*', '*what influence do big data and artificial intelligence have on the labour market, the fulfilment of tasks and the recruitment process*', and '*to what extent do technological developments and automation lead to a change in the 'employability' of employees at different educational levels and within different sectors*' (Bouma et al., 2018, p. 19). In other words, how can we assess and understand the effects of Industry 4.0 when there is no prominent presence of that which we wish to comprehend?

Besides practitioners and scholars creating Industry 4.0 maturity scales, recent research has focused on the lagging Industry 4.0 adoption by addressing the benefits and/or challenges of Industry 4.0 implementation (e.g. Müller, Kiel, & Voigt, 2018; Orzes, Rauch, Bednar, & Poklemba, 2018). Despite being an essential approach, the highlighted issue is currently dominated by an implementation-oriented discussion. Yet, in addition to insights into barriers that hinder the realisation of Industry 4.0, the perspective of a motive that substantiates the implementation of Industry 4.0 should also be addressed. An approach which, so far, received little and fragmented attention.

In response, study 4, attempts to expand the current viewpoint towards the lagging presence of Industry 4.0 by shifting the focus to a preceding step, the decision-making phase. As part of this, the study develops an Industry 4.0 strategic decision-making (SDM) typology framework. This offers an integrated perspective on the motives underlying the decision to opt for Industry 4.0 in order to address the research aim of *illustrating the complexity and importance of the decision-making phase surrounding Industry 4.0.*

Table 1.3 Overview of research challenges and subprojects

Study	Challenges	Research aim or question	Key concepts & theories	Methods
CHAPTER 2	Research into Industry 4.0 is lacking a HRM perspective	Encourage and guide Smart Industry HRM-related research	Smart Industry; Job design	Developed overview of the existing body of work related to job design
CHAPTER 3	Clear meaning of labels denoting phenomenon are absent, and purpose of diversity unclear	What is the value of Smart Industry?	Smart Industry; Industry 4.0; Conceptualiza-tions of technology	20 Interviews with Dutch Smart Industry experts that focused on one question
CHAPTER 4	The social work context is missing from research into characteristics of jobs within an Industry 4.0 context	What developments can be observed with respect to the social context of work as a result of the Industry 4.0 work context?	Industry 4.0; Social work characteristics	13 Semi-structured interviews divided over 2 technical service providers & 2 production companies
CHAPTER 5	Application of Industry 4.0 is lagging behind and research mainly directed to phase of implementation	Illustrate the complexity and importance of the decision-making phase surrounding Industry 4.0	Industry 4.0; Institutional theory; Strategic management; Decision-making	Case study based on secondary (interview) data from 8 cases

1.5 Research approach

"Researchers explore when they have little or no scientific knowledge about the group, process, activity or situation they want to examine but nevertheless have reason to believe it contains elements worth discovering" (Stebbins, 2001, p. 6). In line with the above quote, the phenomenon being examined – Industry 4.0 – could reasonably be considered a relatively new field at the start of this PhD project. Scientific knowledge was thus scarce. Nevertheless, as previously discussed, various factors led to the assumption that Industry 4.0 would become noteworthy and require a huge effort by scientists from different disciplines;

among which HRM scholars. In addition, the relevance or worthiness of exploring Industry 4.0 from an HRM perspective is reflected in the first paper of this dissertation which is conceptual in nature. In other words, the study in Chapter 2 intends to point out the importance of raising questions and conducting research on Industry 4.0 from a more social, or human resource management, perspective. The three remaining studies in this dissertation are empirical and based on qualitative assessments. Despite the fact that both quantitative and qualitative assessments are applicable for exploration, qualitative data predominates in most exploratory studies (Stebbins, 2001). Qualitative approaches, for instance documents or interactions, seek to "understand how people construct the world around them, what they are doing, how they are doing it or what is happening to them in terms that are meaningful and that offer rich insights" (Flick, 2018, p. 5). Consequently, it fits the two main research questions raised. Before turning to the discussion of the research design for the three empirical studies, an overview is given in which the various sources that contributed to the knowledge presented in this dissertation are highlighted.

1.5.1 Data collection

As most scholars will be aware of, knowledge can be gained through reading a large number of academic publications and/or reports from practice that pertain to the topic of interest – in this case Industry 4.0 – as well as attending conferences related to your specific field of research. Other sources that contributed to the experiences and insights gained throughout my PhD project are presented in Table 1.4 and includes primary and secondary data sources.

Table 1.4 Overview of knowledge sources

Type of source	Source details
Held conversations / interviews	40 members of the Twente association for HRM directions (CPE)
	20 Dutch Smart Industry experts
	6 HRM experts from the Dutch HRM Network
	2 members of an engineering firm (Qing)
	A director of an association that represents companies in the Eastern part of the Netherlands (VMO)

	A management consultant at the Dutch employers' organisation in the technology industry (FME)
Engagement with organisations	Aebi Schmidt, Bosch, Bronkhorst, Bruil, De Cromvoirtse, Demcon, Eaton industries, Electromach Stahl, GS Metaal, Hellebrekers Techniek, Hollander Techniek, House of Blue Jeans, Itter, Kornelis Caps & Closures, Philips consumer lifestyle, Royal Auping, Thales, Trumpf and Van Raam Rijwielen
Co-writer of the *Smart Industry roadmap: Onderzoeksagenda voor HTSM en ICT en routekaart voor de NWA*	For a full list of the 30 contributors see the roadmap itself (Ahsmann et al., 2018)
Participative observations at Smart Industry events	Smart Industry congress, Delft, 2015 Smart Industry year event, Utrecht 2017 Smart Industry year event, Bussum, 2018

1.5.2 Methodologies

The main body of the study presented in Chapter 3, which assesses the value of Smart Industry, centred around interviews held with Smart Industry experts in the Netherlands. To obtain the fullest possible understanding of the Smart Industry label, the interviews were kept as open as possible. Topics were thus participant-driven and, as a result, interviews resembled more like everyday conversations (Roulston & Choi, 2018). Before the interviews, a document analysis was conducted to illustrate available descriptions of Smart Industry in reports from the Dutch Smart Industry team, and highlight the need for further analysis based on the conducted interviews. Considered reports stemmed from Smart Industry events that were attended or accessed via websites linked to the initiators of Smart Industry in the Netherlands. Finally, documents – a dictionary definition and (academic) publications – were used to enable a comparison between existing descriptions of Industry 4.0 or the 4th industrial revolution and the representation of Smart Industry derived from the interview data.

Chapter 4 focuses on developments within the social context of work as a result of Industry 4.0. Semi-structured interviews were carried out to identify changes in work-related social interactions due to Industry 4.0. A semi-structured approach was chosen since each interview was guided by the following format or topics: the four social work characteristics derived from literature and the role played by Industry 4.0 technology within the mentioned changes to these characteristics.

Finally, the study discussed in Chapter 5 utilised secondary data (i.e. transcripts or reports based on interviews conducted by others) to build an Industry 4.0 strategic decision-making typology depicting organisational motives underlying the decision to opt for Industry 4.0. The original goal in publishing these data is assumed to be to present Dutch frontrunners, by giving them a platform to showcase their progress, regarding the Industry 4.0 phenomenon. As a result, the data from the selected cases offered unique and objective – not steered by our assumptions – insights into organisations' motives for deciding to adopt Industry 4.0. As an additional input, to strengthen findings where possible, relevant data from the websites of the selected firms were used.

1.6 Outline of the dissertation

This chapter provides an introduction to Industry 4.0 as well as an explanation of the motivation, the challenges that arose, the research subprojects, and the adopted methodology. The next chapters contain four scientific papers, three of which have been published as peer-reviewed book chapters and one which was presented at an international conference. The published papers are presented in their original form, albeit with some minor alterations in layout.

In Chapter 2, our position in the employment debate is discussed, leading to the development of Smart Industry related challenges stemming from a job design lens. Following arisen challenges linked to the phenomenon itself, Chapter 3 assessed the value of the Dutch Smart Industry label. Based on the findings, a switch to the term Industry 4.0 is made. Chapter 4 returns to the impact of the phenomenon by adopting the developed definition to analyse its effect on the social context of work. Observations regarding the presence of the phenomenon, and the existing research focus linked to this matter, resulted in Chapter 5. Emphasis in this chapter is on offering an additional, decision-making perspective to the research attention dominating thus far.

These four chapters are followed by a final chapter that answers the two main research questions and discusses implications and future research options.

A schematic outline of chapters and their interrelations is shown in Figure 1.3.

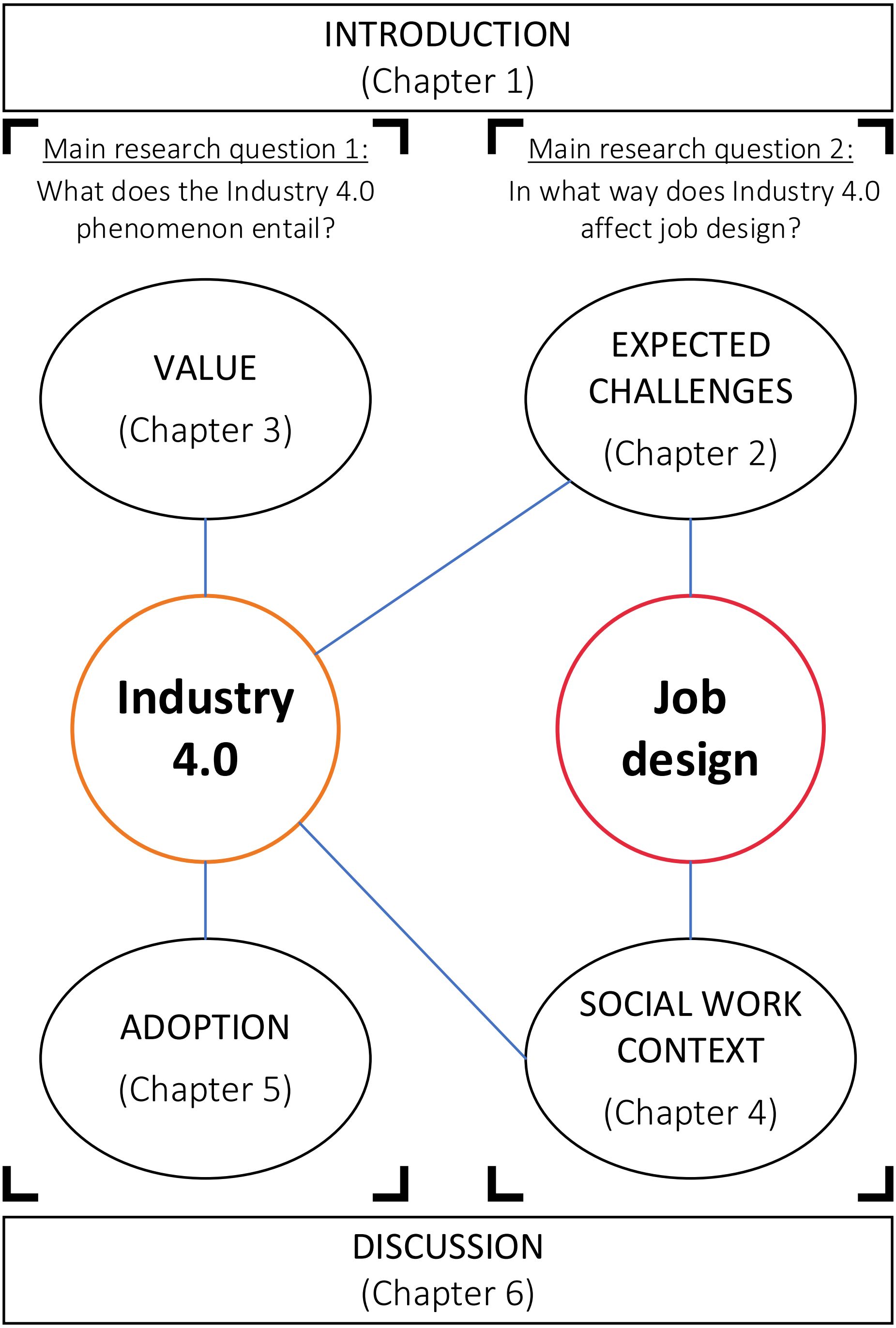

Figure 1.3 Outline of the dissertation

CHAPTER 2

Smart Industry research in the field of HRM: Resetting job design as an example of upcoming challenges

Time box 2:
In 2015-2016, Industry 4.0 was still a relatively new field, but showing signs that it would become noteworthy. Requiring effort from, and opening up opportunities for a diverse set of research fields, including HRM. These efforts needed to be highlighted and encouraged. Moving the social discussion beyond the, then, dominating employment debate.

This chapter is published as Habraken, M., & Bondarouk, T. (2017). Smart Industry research in the field of HRM: Resetting job design as an example of upcoming challenges. In T. Bondarouk, H. Ruël, & E. Parry (Eds.), *Electronic HRM in the smart era* (pp. 221-259). Bingley, UK: Emerald Publishing Limited.

A preliminary version of this paper was presented at the 6th International e-HRM Conference, 27-28 October 2016, Enschede, the Netherlands.

Abstract

Purpose: This chapter aims to encourage and guide Smart Industry HRM-related research by addressing upcoming challenges developed using a job design lens.

Methodology/approach: The challenges are constructed based on a developed overview of the existing body of work related to job design and a description of Smart Industry.

Research implications: The challenges are meant as an indication of the issues that arise within job design due to Smart Industry and, in so doing, suggest directions for future research in this specific field. Additionally, through laying out challenges for this particular example, the chapter encourages scholars to consider the possible impact of Smart Industry within other HRM areas.

2.1 Introduction

Smart Industry is called not just a mere vision but the future as well as the world's fourth industrial revolution (Huizinga et al., 2014). Characterised by technology, digitisation and connectivity, it is a frequently discussed topic as visible from the numerous events and documents on websites and online reports that focus on this movement. The above indicated attention paid to Smart Industry, however, contrasts starkly with the number of existing academic contributions. A Web of Science search on 'Smart Industry' resulted in only 11 hits. Related labels like 'Industry 4.0' and 'Industrial Internet of Things' (Davies, 2015; Huizinga et al., 2014) provided more results on Web of Science (respectively 254 and 65 hits), yet these papers still hardly adopt a human resource management (HRM) approach. Analysing the research areas for papers on both labels shows a strong emphasis on the research areas of engineering and computer science rather than HRM. This finding confirms the statement by Vacek (2016, pp. 731-732) that "the concept of Industry 4.0 is primarily being explored from a technical point of view – robotics, Internet of Things, big data, smart objects, and smart factories. There has been relatively little enquiry into the question of what it means for people and our society on the whole". In short, despite the new opportunities for research that Smart Industry, and related labels, opens up given its appellation as the fourth industrial revolution, they are currently not being taken up by scholars in the field of HRM.

Given its description as "all those activities affecting the behaviour of individuals in their efforts to formulate and implement the strategic needs of the business" (Schuler, 1992, p. 30), HRM touches most parts of any firm. Introducing drastic organisational changes, as is the case with Smart Industry, will therefore not take place without impacting factors related to HRM. The purpose of this chapter is to encourage and guide Smart Industry HRM-related research. The HRM field, however, is a vast research area – a review of it over the past 23 years by Markoulli, Lee, Byington, and Felps (2016) revealed 1702 article topics. Consequently, we shall adopt the topic job design – considered here as the use of job characteristics to (re)arrange work – to address upcoming challenges, hence areas of research, deriving from Smart Industry. Job design was chosen for several reasons. First, it has been and still is a topic of great interest (Oldham & Fried, 2016), and its characteristics have been found to correlate with various important outcomes – attitudinal outcomes such as job satisfaction and internal work motivation, behavioural outcomes such as performance and turnover, cognitive outcomes such as role perceptions and wellbeing outcomes such as stress and burnout (Humphrey et al., 2007). Job design further fits with the present employment debate surrounding Smart Industry. That is, in disagreeing with a jobless future perspective, as we do (more details follow later), issues regarding the (re)arrangement of work logically follow. Finally, job design incorporates the current focus on skills visible within online reports (Berger & Frey, 2015; FME, 2015; Levy & Murnane, 2013; Ten Have et al., 2014) but is not limited to it. In other words, job design extends the skills focus, a knowledge aspect of work, through its incorporation of task, social and contextual aspects of work (Morgeson & Humphrey, 2006).

In integration, the present work aims to guide research connected to the Smart Industry movement in the field of HRM by addressing upcoming challenges developed using a job design lens. The discussion started early in 2016 within a smaller research project conducted by Habraken (2016) and is built on here. In the next section, a short overview of the current state and our perspective regarding the employment debate will be provided since they impact the relevance of an HRM focus on Smart Industry; a jobless future does not require HRM, as an extreme example. After that, an overview of the existing body of work related to job design will be presented followed by a description of the concept of Smart Industry. We then turn our attention to the job design challenges for Smart Industry.

2.2 The employment debate – current state and our perspective

Smart Industry again awakens the discussion surrounding the possibility of massive unemployment, as did previous major technological changes (e.g. Kool, Van Est, Van Keulen, & Van Waes, 2015). This next part therefore briefly covers the existing discussion and clarifies the view adopted within this debate.

In the classic debate regarding the relationship between technological change and employment, two opposing visions predominate. First, the *upward spiral*: technological innovation gives rise to higher labour productivity which in turn generates lower manufacturing costs, cheaper products, increasing purchasing power, a growing market and eventually more jobs. Second, there is the *downward spiral*: technological innovation gives rise to higher labour productivity, but here this is seen as resulting in a decrease in jobs as labour is widely replaced by technology causing a decrease in purchasing power, lower consumption and a shrinking market (Kool et al., 2015). The presence of two conflicting research camps is further fuelled by the crumbling of an existing consensus. The dominance of the research view that technological growth comes at the expense of jobs in the short term but rapidly creates new jobs in 1 to 2 years has been falling apart since 2010 (Van der Zee, 2015).

Those belonging to the stream questioning the conventional wisdom include Brynjolfsson and McAfee (2014) and Ford (2015). These authors argue that machines will be replacing people, more than in the past. According to them, the balance between job creation and job loss has shifted towards the latter. Brynjolfsson and McAfee (2014) substantiate their position by highlighting the inability of individual/employee skills and organisations to keep pace with technical change, resulting in the visibility of what these authors term 'the great decoupling'. In other words, a continuing trend of increasing labour productivity but a drop in labour demand. Despite the above, Brynjolfsson and McAfee (2014) suggest that a doomsday scenario is preventable if businesses 'start racing with machines instead of against them'. They propose that organisations are simply not being creative enough, which implies that it takes more creativity to pose the question of 'how can a machine and human interact to do something currently unknown and produce value' compared to the question of 'how can I have a machine take over certain tasks' (Bernstein & Raman, 2015). Ford (2015), however, indicates that robots and other forms of automation are going to consume much of the base of the job skills pyramid while, in addition, the top tier will not remain a safe haven due to developments in artificial intelligence applications. Therefore, a larger number of people will be fighting for an ever smaller number of jobs unless a guaranteed basic income is realised. Adding to the more pessimistic views of future employment are the results of the study conducted by Frey and Osborne (2013), in which 47 per cent of total US employment is estimated to be at risk for computerisation. Similar results are found in many replication studies (e.g. Schattorie, De Jong, Fransen, & Vennemann, 2014; Witteman & Heijne, 2014, October 1). Frey and Osborne (2013) work, however, is seen as being limited to the substitution effect of computerisation since it neglects technology's role in the creation of jobs, the impact of societal forces and/or its solution to existing problems such as the ageing population (e.g. Schattorie et al., 2014; Witteman & Heijne, 2014, October 1).

Unlike those viewing a more gloomy future, Miller and Atkinson (2013) present a brighter perspective. They state that the pessimists are wrong in their postulated link between technological change and employment. The main reason Miller and Atkinson (2013) provide for their assumption that robots will not leave us massively unemployed is that human needs are close to infinite and, hence, as long as that is the case, there will also be a continuing need for labour. Another positive viewpoint is given by Bainbridge (2015) who, besides the argument that technology can also create jobs and bring down barriers of entry, states that people increasingly provide the competitive edge as "competition lies in the quality of service that only people can deliver because people are prepared to pay a little more for quality service and positive interaction" (Bainbridge, 2015, p. 81). Davenport and Kirby (2015) likewise offer a less grim outlook as, in their view, human work can flourish when we reframe automation into augmentation; augmentation "means starting with what humans do today and figuring out how that work could be deepened rather than diminished by a greater use of machines" (Davenport & Kirby, 2015, p. 60). To some extent this view fits with Brynjolfsson and McAfee (2014) statement that we are not being creative enough. Furthermore, Schouteten (2015) highlights the fact that technology in itself does not determine the function structure, and hence employment; but it is the combination and alignment with organisational design principles or organisational choice.

In this work, we adopt the perspective that the technological developments surrounding Smart Industry will not lead to massive unemployment. We acknowledge that certain jobs (perhaps all) might drastically change, but we do not agree with the outlook of a jobless future. Technology is not yet capable of outperforming humans in every aspect (Bernstein & Raman, 2015). Even if this were the case, organisations are still left with a choice – based on firm strategy, for instance – regarding which technological developments are appropriate to implement. As Schouteten (2015) points out, technology in itself does not determine the future, rather it is the decisions we make regarding it. Building on the aspect of choice is the possibility to stop viewing the developments as a means of diminishing current tasks and start seeing them as an opportunity. To conclude, the perspective taken in this chapter is not one of a jobless future and as a result the HRM field remains a relevant area of research regarding the Smart Industry movement. We therefore seek to encourage Smart Industry research within the field of HRM through our specific focus on job design. In the next few sections the creation of an overview of existing research on job design will be addressed in order to aid the discussion surrounding the challenges pointed out from Section 2.7 onwards.

2.3 Job design – background and adopted theory

The roots of contemporary approaches to job design can be traced back to the economic perspective of the division of labour. Around the time of the first industrial revolution, economists such as Adam Smith (1776) and Babbage (1835) promoted the idea of breaking down jobs into simple tasks as a way to improve performance. Through the work of Taylor (1911), the concept of simplification – dubbed *scientific management* – gained momentum at the beginning of the twentieth century. These principles are efficiency-oriented but lead to boring and repetitive work, which sparked a human relations movement intended to improve worker satisfaction and motivation by focusing on job enrichment. An important body of work within the job enrichment approach involves the *motivator-hygiene theory* proposed by Herzberg, Mausner, and Snyderman (1959). Despite several studies generally failing to confirm its key aspects, this theory is considered influential since it drew attention to the possibility of enhancing satisfaction; it served as the foundation for the interest in job enrichment. Research addressing the weaknesses of this theory eventually developed into the job characteristics model (JCM), most fully articulated by Hackman and Oldham (1976) (for more insights on these and other approaches see, e.g. Grant, Fried, & Juillerat, 2011; Morgeson et al., 2012; Parker, Wall, & Cordery, 2001)

In creating an overview of the existing scholarly work on job design, the current chapter adopts the JCM as its basis from which to build the overview. This choice stems from the fact that we side with the brighter perspective in the employment debate. As previously stated, within the context of Smart Industry, human work can flourish when we reframe automation (scientific management) into augmentation (job enrichment; "work could be deepened rather than diminished by a greater use of machines" - Davenport & Kirby, 2015, p. 60). We therefore focus on existing job enrichment approaches, specifically the JCM, since it provides a clear framework regarding essential factors while overcoming problems of the motivator-hygiene theory.

2.4 Method

To elaborate on the research goal of this chapter, we purposefully selected existing overviews and amplifications on the JCM to avoid creating a popularly structured literature review. We used the JCM of Hackman and Oldham (1976) as our starting point and were guided by available overviews developed further in the 2000s, specifically one review paper by Morgeson and Campion (2003) and one by Morgeson et al. (2012). We were also sensitive to the fact that other authors addressed job characteristics, too (Grant et al., 2011; Parker et al., 2001). These papers cover various publication years and several viewpoints on the JCM. Although the model by Parker et al. (2001) includes a separate part on group-level characteristics, the factors mentioned there correspond with job characteristics from what these authors called the 'individual level'. Consequently, the present chapter presents one overview, but these characteristics could be considered from either an individual- or group-level perspective. To bring structure to the list of identified job characteristics, the categorisation by Morgeson and Humphrey (2006) is adopted due to the cited status of this paper (361 times based on Web of Science in December 2016). Job characteristics that were not included in Morgeson and Humphrey (2006) paper are grouped together under the category ‘unclassified’.

To capture an impression of the relations found between the identified job characteristics and outcome variables, mediators, moderators and the factors themselves, a selection of exemplary papers was assembled using the four review/conceptual papers stated above. These papers addressed the field of interest and as a result referred to empirical work that was of relevance for the overview, for instance the meta-analysis and highly cited paper by Humphrey et al. (2007; cited 392 times based on Web of Science in December 2016). As the results from the paper by Morgeson and Humphrey (2006) were incorporated in the meta-analysis by Humphrey et al. (2007), these findings were only stated for those factors not included in the study by Humphrey et al. (2007). A Web of Science search – using work/job AND characteristics with year 2005[7]-2016 or 2016 and the refinements article, management and business – was further conducted to identify, in particular, papers examining mediating, moderating and/or interaction effects, such as Pee and Chua (2016). Regarding the relationships shown, we picked up empirical findings with a p value equal or less than .05.

2.5 JCM and developments

The JCM (Hackman & Oldham, 1976) includes five characteristics (skill variety, task significance, task identity, autonomy and feedback) and proposes that they give rise to three critical psychological states (experienced meaningfulness of the work, experienced responsibility for outcomes of the work and knowledge of the actual results of the work activities). Specifically, the theory highlights that the first three characteristics contribute to experienced meaningfulness, autonomy affects the level of experienced responsibility and feedback provides knowledge of the actual results. These psychological states, in turn, impact five outcomes (internal work motivation, performance, satisfaction, absenteeism

[7] The year 2005 was used as a starting point since the meta-analysis by Humphrey et al. (2007) incorporated papers up to 2004.

and turnover). Hackman and Oldham (1976) further added growth need strength (GNS) as a moderator to their model. Research since then has examined the relations included in the JCM and proposed additions – new characteristics, outcomes and different mediating as well as moderating factors. Table 2.1 presents an overview of the developments regarding job design; Figures 2.1 and 2.2 graphically illustrate the information within this table.

2.5.1 Identified job characteristics

The analysis led to the identification of 29 different job characteristics; the factors dealing with others/task interdependence and friendship opportunities/social support have changed with respect to naming but are similar enough in meaning to be considered as a development within one factor. Table 2.1 displays the definitions of the characteristics. Appendix A provides a list of the job characteristic definitions adopted; they are grouped based on their respective category as highlighted by Morgeson and Humphrey (2006) – task, knowledge, social or contextual characteristics – or in the unclassified category if the specific characteristic was not included in Morgeson and Humphrey (2006) framework.

2.5.2 Graphical illustrations

Figure 2.1 presents the findings from a job characteristic (antecedent) perspective and Figure 2.2 presents them from an outcome perspective.

The identified characteristics are found to be associated with attitudinal, behavioural, cognitive and/or well-being-related outcomes. In particular, the factors belonging to the task and social characteristics categories were linked to many of these outcome variables. In contrast, most factors in the unclassified category were not correlated to any outcome variable. It is surprising, however, that the same applies to equipment use. Considering the three psychological states proposed by Hackman and Oldham (1976) – experienced meaningfulness, experienced responsibility and knowledge of actual results – only the first two operated as theorised in the JCM.

Empirical support was found for nine new mediators: two dimensions of psychological empowerment (meaning & competence), three knowledge characteristics (perceived value of knowledge, knowledge renewal &knowledge

breadth), social worth and impact, work engagement and psychological contract fulfilment. Most of the effects studied made use of the five core characteristics. The majority of the effects are further linked to attitudinal outcomes and performance.

With respect to moderators, Hackman and Oldham (1976) growth need strength was connected to conflicting findings (Morgeson et al., 2012) and therefore not included in the constructed overview. In later years, support was found for other individual moderators – conscientiousness, temporal focus, prosocial value. Two non-individual moderators (production uncertainty and social intensity) were also present. The main factors used to study these moderators included the characteristics task significance, social support or autonomy. Regarding the outcomes side, they were linked to the variables performance, satisfaction, organisational commitment, role conflict, role ambiguity and/or turnover intentions.

Finally, little to no research was found addressing interaction effects between two or more work characteristics or considering the work characteristics from an integrated systems perspective. For instance, with respect to the first case (interaction effects between two or more factors), Birtch, Chiang, and Van Esch (2016) and Butler, Grzywacz, Bass, and Linney (2005) address this issue. However, they adopt the broadly defined characteristic ‘job demands’ (e.g. “I had too many demands on me at work today”; Butler et al., 2005, p. 160) within the examined interactions, making the effects unsuitable for the identified job characteristics. The study by Liden, Wayne, and Sparrowe (2000), in addition, adopts a bundle of work characteristics. Its use, however, suggests the construction of a high-order construct rather than the investigation of an integrated system of interrelated activities (Delery & Doty, 1996).

Table 2.1 Overview of developments and findings regarding job characteristics (JC)

Cate gory	**JC**	**Definition(s);** historically arranged	**Empirical findings**	
			Outcomes	*Mediation / Moderation / Interactions & systems*
TASK	TS	"The degree to which the job has a substantial impact on the lives or work of other people, whether in the immediate organization or in the external environment" (Hackman & Oldham, 1976, p.257) "The degree to which a job influences the lives or work of others, whether inside or outside the organization" (Morgeson & Humphrey, 2006, p.1323; based on Hackman & Oldham, 1975)	Positive correlations Performance; Overload; Organisational commitment; Job involvement; Internal work motivation; Knowledge contribution; Work engagement (Christian et al., 2011; Fried & Ferris, 1987; Humphrey et al., 2007; Pee & Chua, 2016) Negative correlations Burnout/exhaustion (Humphrey et al., 2007)	(partial) Mediation Experienced meaningfulness; Perceived value of knowledge; Social impact; Social worth; Work engagement (Christian et al., 2011; Grant, 2008; Humphrey et al., 2007; Pee & Chua, 2016) Moderation Conscientiousness; Prosocial values (Grant, 2008) Interactions and systems Included in an adopted bundle of work characteristics (Liden et al., 2000)
	TI	"The extent to which employees do an entire or whole piece of work and can clearly identify the result of their efforts" (Hackman & Lawler, 1971, p.265) "The degree to which the job requires completion of a "whole" and identifiable piece of work; that is, doing a job from beginning to end with a visible outcome" (Hackman & Oldham, 1976, p.257) "The degree to which a job involves a whole piece of work, the results of which can be easily	Positive correlations Performance; Satisfaction; Organisational commitment; Job involvement; Internal work motivation; Knowledge contribution (Fried & Ferris, 1987; Humphrey et al., 2007; Pee & Chua, 2016) Negative correlations Absenteeism; Role conflict; Stress; Burnout/exhaustion (Humphrey et al., 2007)	(partial) Mediation Experienced meaningfulness; Perceived value of knowledge; Knowledge renewal; Knowledge breadth (Humphrey et al., 2007; Pee & Chua, 2016) Interactions and systems Included in an adopted bundle of work characteristics (Liden et al., 2000)

		identified" (Morgeson & Humphrey, 2006, p.1323; based on Hackman & Lawler, 1971)		
	TV	"The degree to which a job requires employees to perform a wide range of operations in their work and/or the degree to which employees must use a variety of equipment and procedures in their work" (Hackman & Lawler, 1971, p.265) "Refers to the degree to which a job requires employees to perform a wide range of tasks on the job" (Morgeson & Humphrey, 2006, p.1323)	**Positive correlations** Performance; Overload; Satisfaction; Work engagement (Christian et al., 2011; Humphrey et al., 2007)	**(partial) Mediation** Work engagement (Christian et al., 2011)
	A	"The extent to which employees have a major say in scheduling their work, selecting the equipment they will use, and deciding on procedures to be followed" (Hackman & Lawler, 1971, p.265) "The degree to which the job provides substantial freedom, independence, and discretion to the individual in scheduling the work and in determining the procedures to be used in carrying it out" (Hackman & Oldham, 1976, p.258) *No definition* (Parker et al., 2001) Indication of the construct *timing control* which "reflects the opportunity to determine the scheduling of work" and *method control* which "refers to the choice of how to carry out tasks" (Morgeson & Campion, 2003, p.434) "Includes three interrelated aspects centred on freedom in (a) work scheduling, (b) decision making, and (c) work methods" (Morgeson & Humphrey, 2006, p.1323)	**Positive correlations** Performance; Satisfaction; Organisational commitment; Job involvement; Internal work motivation; Creativity; Innovation; Personal initiative; Safety engagement; Work-family facilitation; Knowledge contribution; Work engagement (Birtch et al., 2016; Butler et al., 2005; Christian et al., 2011; Fried & Ferris, 1987; Humphrey et al., 2007; Nahrgang et al., 2011; Ohly, et al., 2006; Pee & Chua, 2016; Shipp et al., 2009; Wright & Cordery, 1999) **Negative correlations** Absenteeism; Role ambiguity & conflict; Anxiety; Stress; Burnout/exhaustion; Accidents + injuries; Adverse events; Unsafe behaviour; Work-family conflict; Turnover intentions (Butler et al., 2005; Fried & Ferris, 1987; Humphrey et al., 2007; Nahrgang et al., 2011; Shipp et al., 2009)	**(partial) Mediation** Experienced responsibility; Psychological contract fulfilment (Birtch et al., 2016; Humphrey et al., 2007) **Moderation** Production uncertainty; Temporal focus (Shipp et al., 2009; Wright & Cordery, 1999)

TASK & SOCIAL	F	"The degree to which employees receive information as they are working which reveals how well they are performing on the job" (Hackman & Lawler, 1971, p.265) – can stem from task itself or some other person "The degree to which carrying out the work activities required by the job results in the individual obtaining direct and clear information about the effectiveness of his or her performance" (Hackman & Oldham, 1976, p.258) Distinction feedback from job (which is the same as Hackman & Oldham's feedback concept) and feedback from others which "reflects the degree to which others in the organization provide information about performance" (Morgeson & Humphrey, 2006, p.1324; based on Hackman & Lawler, 1971)	FROM JOB **Positive correlations** Performance; Satisfaction; Organisational commitment; Job involvement; Internal work motivation; Knowledge contribution; Work engagement (Christian et al., 2011; Fried & Ferris, 1987; Humphrey et al., 2007; Pee & Chua, 2016) **Negative correlations** Absenteeism; Role ambiguity & conflict; Anxiety; Stress (Fried & Ferris, 1987; Humphrey et al., 2007) FROM OTHERS **Positive correlations** Performance; Satisfaction; Job involvement; Internal work motivation (Humphrey et al., 2007) **Negative correlations** Turnover intentions; Stress; Burnout/exhaustion (Humphrey et al., 2007)	**(partial) Mediation** Knowledge of results; Knowledge renewal (Humphrey et al., 2007; Pee & Chua, 2016) **Interactions and systems** Included in an adopted bundle of work characteristics (Liden et al., 2000)
SOCIAL	SI/C IOO	*No definition* (Parker et al., 2001) "The extent to which the job requires employees to interact and communicate with individuals external to the organization" (Morgeson & Humphrey, 2006, p.1324)	INTERACTION OUTSIDE ORG. **Positive correlations** Satisfaction (Humphrey et al., 2007)	
	FO SS	"The degree to which a job allows employees to talk with one another on the job and to establish informal relationships with other employees at work" (Hackman & Lawler, 1971, p.265) *No definition* (Morgeson & Campion, 2003)	**Positive correlations** Performance/Effort; Satisfaction; Organisational commitment; Job involvement; Internal work motivation; Creativity; Innovation; Personal initiative;	**(partial) Mediation** Psychological contract fulfilment (Birtch et al., 2016) **Moderation**

		"Reflects the degree to which a job provides opportunities for advice and assistance from others" (Morgeson & Humphrey, 2006, p.1324) – incorporates both previous notions of support from coworkers/supervisors & above-mentioned friendship opportunities	Safety engagement & compliance; OCB; Work engagement (Birtch et al., 2016; Chiaburu & Harrison; 2008; Christian et al., 2011; Humphrey et al., 2007; Nahrgang et al., 2011; Ohly et al., 2006) **Negative correlations** Absenteeism; Turnover intentions; Role ambiguity & conflict; Anxiety; Stress; Burnout/exhaustion; Overload; Accidents + injuries; Adverse events; Unsafe behaviour; CWB (Chiaburu & Harrison; 2008; Humphrey et al., 2007; Nahrgang et al., 2011)	Social intensity (Chiaburu & Harrison, 2008)
	DWO TI (I&R)	"The degree to which a job requires employees to deal with other people (either customers, other company employees, or both) to complete the work" (Hackman & Lawler, 1971, p.265) "The degree to which the job depends on others and others depend on it to complete the work" (Morgeson & Humphrey, 2006, p.1324), with initiated being "the degree to which work flows from a particular job to one or more other jobs" and received "the extent to which a person in a particular job is affected by the workflow from one or more other jobs" (Kiggundu, 1981, p.501)	**Positive correlations** Performance; Satisfaction; Organisational commitment; Job involvement; Internal work motivation (Humphrey et al., 2007) **Negative correlations** Turnover intentions; Stress (Humphrey et al., 2007)	
KNOW LEDGE	SV	"The degree to which a job requires a variety of different activities in carrying out the work, which involve the use of a number of different skills and talents of the person" (Hackman & Oldham, 1976, p.257) *No definition* (Parker et al., 2001)	**Positive correlations** Satisfaction; Organisational commitment; Job involvement; Internal work motivation; Knowledge contribution (Fried & Ferris, 1987; Humphrey et al., 2007; Pee & Chua, 2016) **Negative correlations**	**(partial) Mediation** Experienced meaningfulness; Knowledge breadth (Humphrey et al., 2007; Pee & Chua, 2016) **Interactions and systems**

		"Reflects the extent to which a job requires an individual to use a variety of different skills to complete the work" (Morgeson & Humphrey, 2006, p.1323)	Absenteeism (Fried & Ferris, 1987)	Included in an adopted bundle of work characteristics (Liden et al., 2000)
	JC	"The extent to which the tasks on a job are complex and difficult to perform" (Morgeson & Humphrey, 2006, p.1323)	**Positive correlations** Performance; Overload; Satisfaction; Job involvement; Creativity; Innovation; Personal initiative; Work engagement (Christian et al., 2011; Humphrey et al., 2007; Ohly et al., 2006)	
	PS	Part of cognitive demands, *no definition* (Parker et al., 2001) "Reflects the active cognitive-processing requirements of a job" (Morgeson & Campion, 2003, p.434) "Reflects the degree to which a job requires unique ideas or solutions and reflects the more active cognitive processing requirements of a job" (Morgeson & Humphrey, 2006, p.1323)	**Positive correlations** Satisfaction; Work engagement (Christian et al., 2011; Morgeson & Humphrey, 2006)	
	IP	"The degree to which a job requires attending to and processing data or other information" (Morgeson & Humphrey, 2006, p.1323)	**Positive correlations** Satisfaction (Humphrey et al., 2007)	
	S	"The extent to which a job involves performing specialized tasks or possessing specialized knowledge and skill" (Morgeson & Humphrey, 2006, p.1324)	**Positive correlations** Satisfaction (Morgeson & Humphrey, 2006)	
CONTEX TUAL	WC	*No definition* (Parker et al., 2001) "The level of physical activity or effort required in the job" (Morgeson & Humphrey, 2006, p.1324) This factor is sometimes considered broader within empirical papers – for instance also including time	**Negative correlations** Satisfaction; Work engagement (Christian et al., 2011; Humphrey et al., 2007)	

		pressure and workload as mentioned by Grant et al. (2011)		
	PD	"The degree to which a job allows correct or appropriate posture and movement" (Morgeson & Humphrey, 2006, p.1324)	**Positive correlations** Satisfaction (Morgeson & Humphrey, 2006)	
	E	"The variety and complexity of the technology and equipment used in a job" (Morgeson & Humphrey, 2006, p.1324)		
	EU	*No definition* (Parker et al., 2001) "The level of physical activity or effort required in the job" (Morgeson & Humphrey, 2006, p.1324) This factor is sometimes considered broader within empirical papers – for instance also including time pressure and workload as mentioned by Grant et al. (2011)	**Negative correlations** Satisfaction; Work engagement (Christian et al., 2011; Humphrey et al., 2007)	
UNCLASSIFIED	AD	Part of cognitive demands, *no definition* (Parker et al., 2001) "Concerns the degree to which constant monitoring of work is required" (Morgeson & Campion, 2003, p.434; based on Wall et al., 1995) No reference in later papers (e.g. Grant et al., 2011; Morgeson & Humphrey, 2006; Morgeson et al., 2013)		
	EL	"A requirement for individuals to manage their emotional expression in return for wage" (Parker et al., 2001, p.423; based on Hochschild, 1983) No reference in later papers (e.g. Grant et al., 2011; Morgeson & Humphrey, 2006; Morgeson et al., 2013)		

	PR	"Concerns the extent to which an individual can make errors that can result in costly losses of output" (Morgeson & Campion, 2003, p.434) No reference in later papers (e.g. Grant et al., 2011; Morgeson & Humphrey, 2006; Morgeson et al., 2013)		
	OSA RC HWC VW S&AR WDC TH TP	*No definitions* in paper that identifies the characteristic	TIME PRESSURE **Positive correlations** Creativity, Innovation, Personal initiative (Ohly et al., 2006)	

Sources: Birtch et al. (2016); Butler et al. (2005); Chiaburu and Harrison (2008); Christian, Garza, and Slaughter (2011); Fried and Ferris (1987); Grant (2008); Grant et al. (2011); Hackman and Lawler (1971); Hackman and Oldham (1976); Humphrey et al. (2007); Kiggundu (1981); Liden et al. (2000); Morgeson and Campion (2003); Morgeson et al. (2012); Morgeson and Humphrey (2006); Nahrgang, Morgeson, and Hofmann (2011); Ohly, Sonnentag, and Pluntke (2006); Parker et al. (2001); Pee and Chua (2016); Shipp, Edwards, and Lambert (2009); Wright and Cordery (1999).

Abbreviations: TS = task significance; TI = task identity; TV = task variety; A = autonomy; F = feedback; SI/C = social interaction/contact; IOO = interaction outside org.; FO = friendship opportunities; SS = social support; DWO = dealing with others; TI(I&R) = task interdependence (initiated & received); SV = skill variety; JC = job complexity; PS = problem solving; IP = information processing; S = specialisation; WC = work conditions; PD = physical demands; E = ergonomics; EU = equipment use; AD = attentional demands; EL = emotional labour; PR = production responsibility; OSA = opportunity for skill acquisition; RC = role conflict; HWC = home-work conflict; VW = virtual work; SAR = skill & ability requirements; WC = work cycles; TH = temporal horizon; TP = time pressure.

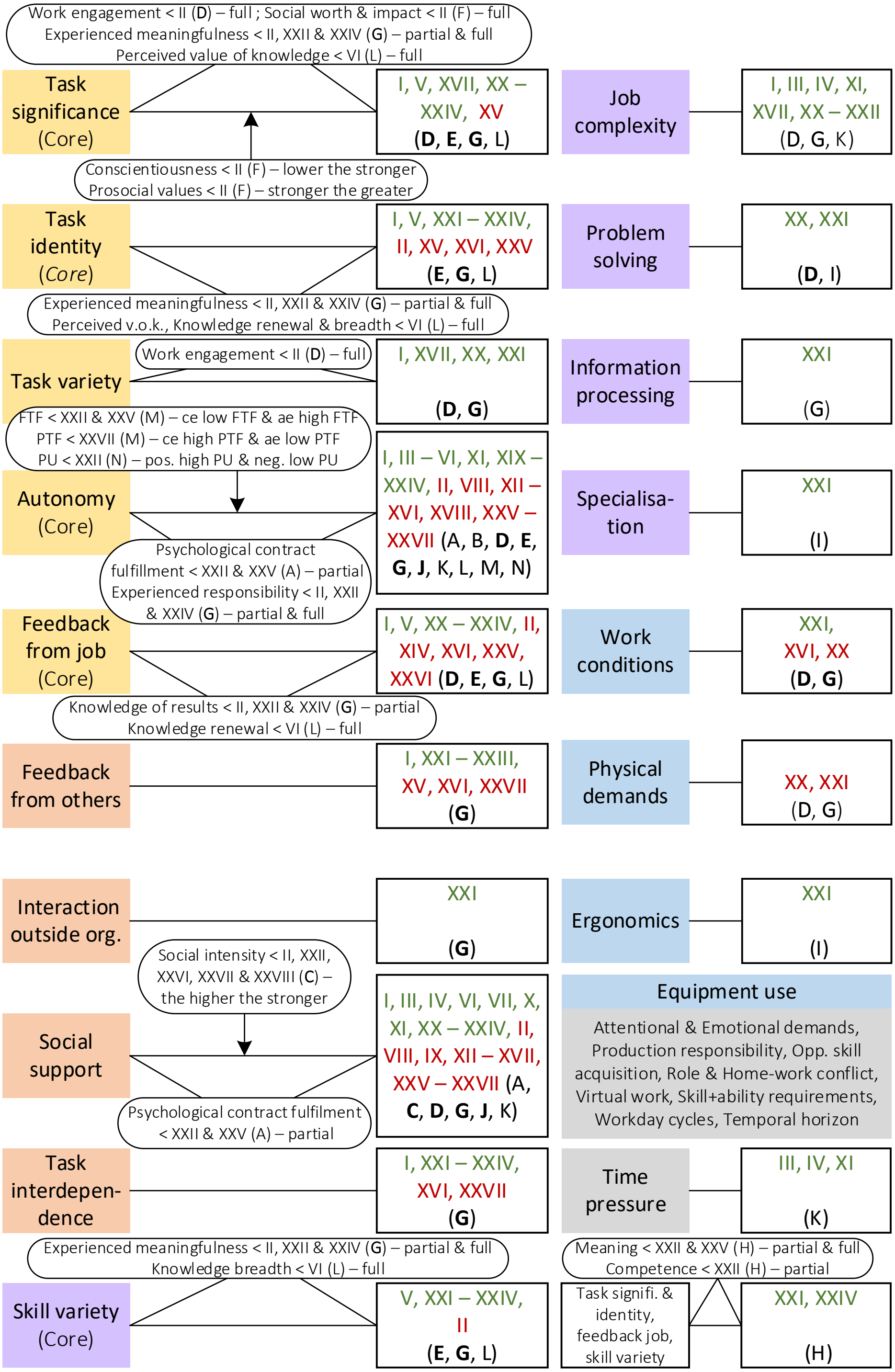

Figure 2.1 Antecedent perspective; for legend and source information see page 46

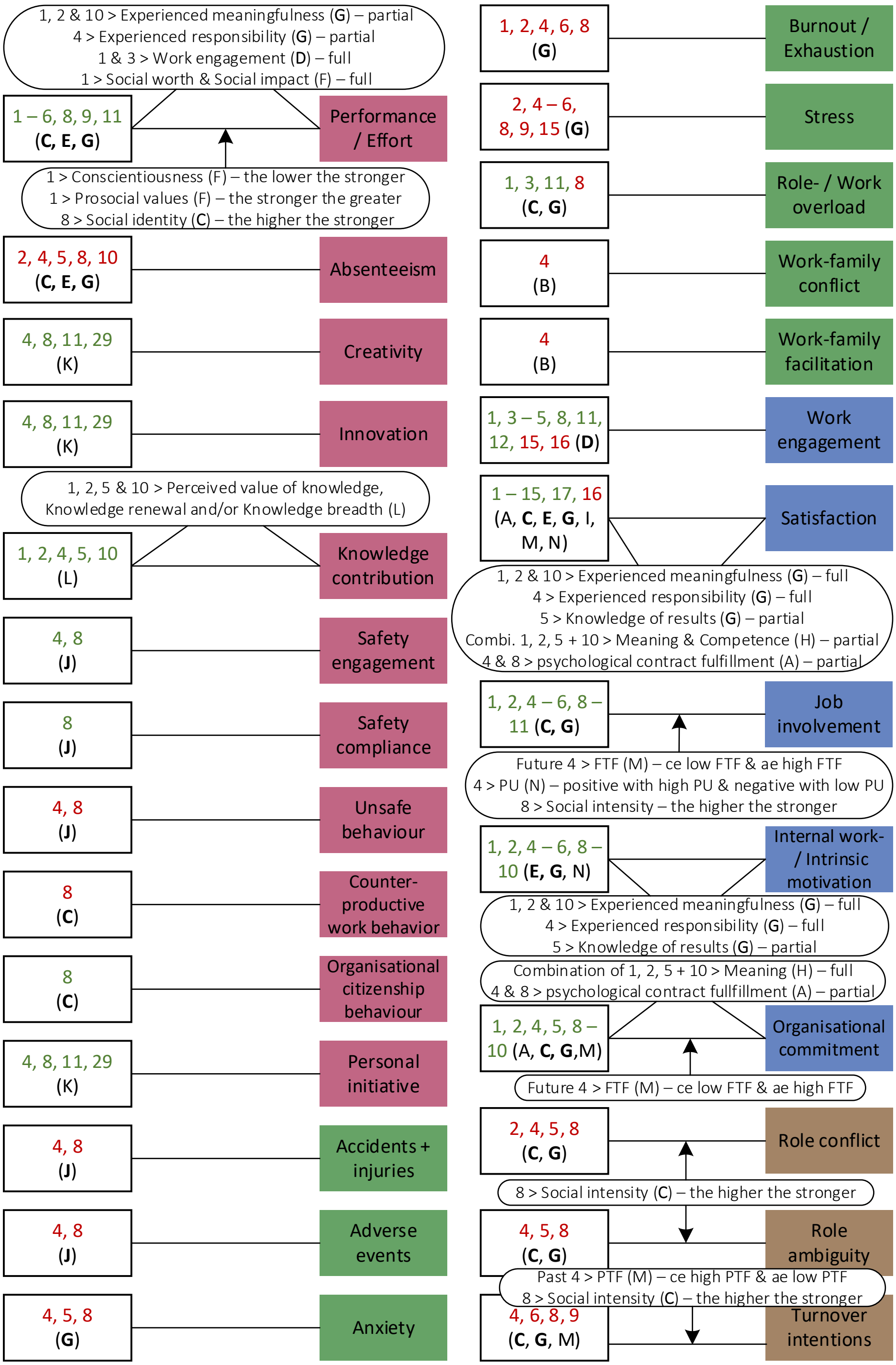

Figure 2.2 Outcome perspective; for legend and source information see page 46

Legend and source information for Figure 2.1 and 2.2

	= Task characteristic		= Contextual characteristic		= Behavioural outcome
	= Social characteristic		= Unclassified characteristic		= Well-being outcome
	= Knowledge characteristic	(Core)	= one of the 5 original factors		= Attitudinal outcome
Number	= Positive correlation	Number	= Negative correlation		= Cognitive outcome
(Letter)	= Reference; **bold** indicates meta-analysis	< and Number or Number and >	= for which outcome or characteristic the effect applies		= Direct correlation; Moderation; Mediation

Abbreviations: FTF = future temporal focus ; PTF = past temporal focus ; PU = production uncertainty ; ce = contrast effect ; ae = assimilation effect ; v.o.k. = value of knowledge

1. Task significance	**2.** Task identity	**3.** Task variety	**4.** Autonomy	**5.** Feedback from job	**6.** Feedback from others	**7.** Interaction outside firm	**8.** Social support
9. Task interdependence	**10.** Skill variety	**11.** Job complexity	**12.** Problem solving	**13.** Information processing	**14.** Specialisation	**15.** Work conditions	**16.** Physical demands
17. Ergonomics	**18.** Equipment use	**19.** Attentional demands	**20.** Emotional labour	**21.** Production responsibility	**22.** Opp. for skill aquisition	**23.** Role conflict	**24.** Home-work conflict
25. Virtual work	**26.** Skill + ability requirements	**27.** Workday cycles	**28.** Temporal horizon	**29.** Time pressure	**= Job design characteristics**		

I. Performance / Effort	**II.** Absenteeism	**III.** Creativity	**IV.** Innovation	**V.** Knowledge contribution	**VI.** Safety engagement	**VII.** Safety compliance	**VIII.** Unsafe behaviour
IX. Counter productive work behav.	**X.** Org. citizenship behaviour	**XI.** Personal initiative	**XII.** Accidents + injuries	**XIII.** Adverse events	**XIV.** Anxiety	**XV.** Burnout / Exhaustion	**XVI.** Stress
XVII. Role- / Work overload	**XVIII.** Work-family conflict	**XIX.** Work-family facilitation	**XX.** Work engagement	**XXI.** Satisfaction	**XXII.** Job involvement	**XXIII.** Internal work- / Intrinsic mot.	**XXIV.** Org. commitment
XXV. Role conflict	**XXVI.** Role ambiguity	**XXVII.** Turnover intentions	**= Outcome variables**				

A Birtch et al., 2016	B Butler et al., 2005	**C** Chiaburu & Harrison, 2008	D Christian et al., 2011	E Fried & Ferris, 1987	F Grant, 2008	**G** Humphrey et al., 2007	H Liden et al., 2000
I Morgeson & Humphrey, 2006	J Nahrgang et al., 2011	K Ohly et al., 2006	L Pee & Chua, 2016	M Shipp et al., 2009	N Wright & Cordery, 1999	**= Reference sources**	

2.6 Smart Industry

One of the most sensitive descriptions of Smart Industry that is currently available is the one presented by Huizinga et al. (2014, p. 17): "industries that have a high degree of flexibility in production, in terms of product needs (specifications, quality, design), volume (what is needed), timing (when it is needed), resource efficiency and cost (what is required), being able to (fine) tune to customer needs and make use of the entire supply chain for value creation. It is enabled by a network-centric approach, making use of the value of information, driven by ICT and the latest available proven manufacturing techniques". What follows from this description is that Smart Industry is characterised by different pillars; specifically network-centric approach or connectivity, digitisation and manufacturing technologies (see also Ten Have et al., 2014). Huizinga et al. (2014, p. 17) also explain the meaning of these three pillars: "high quality, network-centric communication between players, humans and systems, in the entire value network, including the end-users; digitisation of information and communication among all value chain partners and in the production process on all levels; granular, flexible, and intelligent manufacturing technologies, adjustable on the fly to meet highly specific end-user demands". Smart Industry addresses the adoption of aspects such as additive manufacturing, augmented reality and autonomous/intelligent robots within a business process (Bechtold, Lauenstein, Kern, & Bernhofer, 2014; Pluess, 2015; Rüßmann et al., 2015). But, as prior authors also show, the movement is bigger than this; Smart Industry further includes developments in sensors, radio frequency identification (RFID) tags and wireless communication, resulting in the digitisation and connectivity pillar. An example of the latter statement can be found in the description of the Internet of Things (IoT) provided by Whitmore, Agarwal, and Xu (2015, p. 261): "everyday objects can be equipped with identifying, sensing, networking and processing capabilities that will allow them to communicate with one another and with other devices and services over the Internet to achieve some useful objective".

2.7 Job design challenges – for Smart Industry

So far we have placed this chapter within the existing employment debate, provided a background of the current state of affairs about job design and introduced the concept Smart Industry. Let us now turn our attention to the challenges. We claim that there are at least two challenges within the Smart Industry context in the field of job design that need scholarly attention: conceptual clarity and the impact of Smart Industry on job design. Below we elaborate on those challenges.

2.7.1 Conceptual clarity – what is in a name?

The current chapter places emphasis on the concepts of job characteristics and Smart Industry, yet clear definitions seem to be lacking for both aspects. The literature on job design identifies various job characteristics, the majority of which are clearly defined in Appendix A, but surprisingly none of the examined papers provided a definition of the term job characteristic itself; Hackman and Oldham (1976) at one point do refer to 'job dimensions', but this still remains rather vague in terms of a definition. Similarly, a general sense exists of what Smart Industry implies, but an operational definition that empirical studies can use to measure constructs is still missing. The existence of a conceptualization issue is, unfortunately, not an uncommon problem. Suddaby (2010, p. 346) for instance states that "one of the more commonly cited reasons for rejecting a manuscript at AMR is that reviewers feel the submission lacks "construct clarity". The lack of conceptual clarity causes theoretical as well as methodological problems. Regarding the former, Podsakoff, MacKenzie, and Podsakoff (2016, p. 166) indicate that "concepts serve as the fundamental building blocks of theory, allowing us to organise complex phenomena with a common language that, when done well, facilitates communication between researchers". This line of reasoning is supported by, for example, Gerring (1999), Goertz (2006), MacKenzie (2003) and Suddaby (2010). Concerning the methodological aspect, MacKenzie (2003, p. 323) points out that if a focal construct is not adequately defined, it is "difficult to develop measures that faithfully represent its domain", while Suddaby (2010, p. 352) indicates that "improved clarity of constructs enhances researcher's ability to empirically explore phenomena".

The absence of a clear understanding of what a job characteristic entails thus creates issues regarding the assessment of the identified job characteristics as well as the introduction of new ones. For instance, the factor role conflict presented by Parker et al. (2001) could be disputed as a job characteristic since it was also identified as an outcome variable. This example highlights the fact that it becomes essential to be more critical about what we place under the heading of a 'job characteristic', which would be aided by the existence of an agreed upon definition of this concept. A more important concern for this study is the current lack of a more concrete description of what Smart Industry entails. With Smart Industry being an upcoming movement labelled as the fourth industrial revolution, research is and will be interested in the impact it has on various fields. However, with no clear consensual understanding of Smart Industry, the door is left open for scholars to define it in the most convenient manner, potentially leading to a diversity in outcomes. Hermann et al. (2016, p. 3928), although considering the label Industry 4.0, provide support for the nonexistence of a clear meaning regarding the fourth industrial revolution as well as the relevance for it – "a generally accepted understanding of Industry 4.0 has not been published so far. This impedes scientific research as any theoretical study requires a sound conceptual and terminological foundation". As a result, a first challenge is the creation of a clear, consensual understanding and definition for the concepts of job characteristic and Smart Industry.

2.7.2 Impact of Smart Industry on job design

There is no denying that the Smart Industry movement will bring about change. Its labelling as the fourth industrial revolution certainly illustrates this fact since "revolutions are fast, disruptive and destructive" (Blanchet, Rinn, Von Thaden, & De Thieulloy, 2014, p. 7). Examples of expected developments involve changes in existing business models, value chains as well as jobs (Huizinga et al., 2014). Ample research has already focused on the issue surrounding changes in the number of jobs, as evident from the employment debate discussed above. The nature or design of jobs, however, may change as well, giving rise to potential alterations to the constructed overview. This challenges the current understanding that exists regarding job design, leading to a call for research. The next parts address this challenge by exploring direct and moderating effects of Smart Industry on job characteristics and their respective outcome(s) and as a source of inspiration regarding the configurational perspective.

2.8 Direct effects of Smart Industry on job characteristics

Ever since their introduction in the JCM, the core characteristics of task significance, task identity, autonomy, feedback from job and skill variety have been included in multiple revisions and reviews of the JCM (e.g. Grant et al., 2011; Morgeson et al., 2012; Parker et al., 2001). It thus seems unlikely for them to suddenly become obsolete. The following assumptions support this statement: with the introduction of new technological tools, digitisation and connectivity possibilities, employees might require some level of technical, communication and ICT-related skills besides those linked to their present job, resulting in the continuing importance of skill variety. Consider also the presence of task significance due to a shift towards production based on customer order stemming from the increase in flexibility, or of the new feedback from the job potentials due to digitisation, smart machines and connectivity (e.g. computer screens indicating planned and actual production in real time). These assumptions are backed up with findings from a recent empirical study conducted by Bosch (2016). In it, Bosch explored the following research question: 'What are the changes in job characteristics in the era of smart industries and what are the consequences for job design?' By means of nine interviews with general, production and/or HR managers from seven leading Dutch organisations regarding Smart Industry, she investigated anticipated changes in the five core job characteristics that would be brought about by smart industries. We read in her report that interviewees were of the opinion that '*People … will be sooner confronted with the quality of the process they are responsible for. This leads to feedback and offers learning opportunity … [and] … emotional impact increases because employees feel the customer in the factory*'. However, Bosch (2016) data also show that the continuation of core job characteristics is not self-evident to respondents. For instance, one interviewee stated that '*Our employees have less freedom now in when the work is done, but more freedom in improving their work*', hence autonomy still played a role here but in a different form. Additionally, the following quotes question whether or not the individual-level characteristic task identity is feasible in a Smart Industry environment: '*It would be perfect if one team could build a machine from A to Z. But one person performing all these actions, that would be impossible*' and '*We want to reach the point where an engineer can build the product from A to Z,* *including software*'. Bosch (2016) data further show that companies doubt whether or not the discussed developments regarding the core job characteristics are a direct result of Smart Industry: '*Because of all information services there is more information available that can help us look at errors and improvements in production more quickly. However, with all due respect, I do not consider this a result of Industry 4.0. It is a further development of existing systems*'. This emphasises the importance of the first challenge (i.e. conceptual clarity). To conclude, these secondary empirical data findings demonstrate that the complete disappearance of every core characteristic is improbable, yet their continuing use should not be considered self-evident as the quotes on task identity illustrate.

In addition, the manner in which these characteristics continue to exist is subject to change, as shown by the autonomy example. Despite the above conclusion, the questions of to what extent job characteristics will play a role and what that role would be remain unanswered with respect to the other identified characteristics, especially for the currently unclassified characteristics. Theoretical and/or empirical evidence is thus necessary to obtain a complete set of answers and to provide further proof for the stated conclusion. In addition, developments in Smart Industry generate the questions of whether new job characteristics will appear, and if so which ones. This is not the first time that the job context has changed; look at the three prior industrial revolutions. Similar to one of the goals in the paper by Parker et al. (2001), Smart Industry asks if and what expansions of the current range of job characteristics are needed to include aspects salient to the modern Smart Industry context. Let us illustrate this statement with two examples. One example is the introduction of gamification, "the use of game design elements in non-game contexts" (Deterding, Dixon, Khaled, & Nacke, 2011, p. 1). From an organisational perspective, the introduction of gamification has potential benefits as it could enhance staff performance. According to Sailer, Hense, Mandl, and Klevers (2017, p. 37), gamification "can be a work-integrated approach to foster competence development and motivation". Both competence development and motivation are essential factors for performance since abilities or competences are needed in order to perform successfully, yet motivation is often required for their use and development. The implementation of gamification is expected to become easier in a Smart Industry environment due to the increase in digitisation and connectivity involved with this movement. Game design elements such as meaningful stories, avatars, profile development and performance graphs (Sailer et al., 2017) are mainly feasible through digital means. The introduction of more connected, digital aspects in organisations, as a result of Smart Industry, is assumed to aid the adoption of these game design elements. Gamification as a research topic has grown over the past few years (Hamari, Koivisto, & Sarsa, 2014) and, as indicated by Sailer et al. (2017), can bring potential benefits to organisations. Smart Industry could boost its use in organisations due to its digitisation and connectivity pillar resulting in the potential consideration of gamification as a new job characteristic. Research is needed to assess whether the Smart Industry context indeed enhances gamification and to what extent this aids organisations.

Another example stems from the upcoming gig economy – “a way of working that is based on people having temporary jobs or doing separate pieces of work, each paid separately, rather than working for an [permanent] employer” ("Gig economy," n.d.). Through the introduction of online platforms and various apps, a digital connection has become available between different actors, jointly contributing to the business success (e.g. job seekers and the hiring party). In essence, this has become possible due to the changes surrounding the Smart Industry pillars’ digitisation and connectivity. One benefit of the gig economy, mentioned by proponents of the digital earning platforms, is “the ability to turn hobby or pastime into a source of income” (Aaron Smith, 2016, p. 1). For certain people, the fit with hobby or pastime might become an essential aspect of a job and it could become a new job characteristic. As the gig economy introduces a completely different view of work, it might result in more new characteristics or even changes to existing ones (e.g. with organisational structures as currently known disappearing within a gig economy, factors like feedback from others and interaction outside a firm will need to be reconsidered). The gig economy thus raises many questions for future research. Thus, just two examples – gamification and gig economy – offer numerous research and business challenges for if and what extensions of the job characteristics model are needed.

2.9 Smart Industry as moderator

Besides the direct effect that Smart Industry can have on job characteristics, it could also exert an influence via an indirect (moderating) approach. The constructed overview and graphical illustrations present the extensive and varied relationships that have been found between the majority of identified job characteristics and outcome variables. Smart Industry, however, raises the question of whether this new context alters the strength and/or direction of the relationships found. A few expectations stemming from the introduction of the gig economy addressed above will be highlighted below.

One result of this phenomenon could be that people pick jobs/gigs that fit a specific skill that they excel in (e.g. manuscript editing or moving furniture). This could lead to a change in the current positive relation between skill variety and the outcome variables satisfaction and motivation. Consciously choosing jobs, via online platforms and apps, that require the use of one's specific strong points could generate negative reactions when faced with jobs that demand a broad set of skills. This is of special relevance for those gig workers – someone who "earned money in the last year from website or mobile apps that: connect workers directly with people who want to hire them; require workers to create a profile in order to find and accept work assignments; and coordinate payments once the task or job is completed" (Aaron Smith, 2016, p. 2) – who are also employed. However, it would mean a strengthening of the found relationship between specialisation and satisfaction. Additionally, according to 30 per cent of the respondents from a survey conducted between July and August 2016 by Pew Research Center, gig workers "do this type of work because they need to be able to control their own schedule" (Aaron Smith, 2016, p. 3). This would support, and potentially strengthen, the found relationships between autonomy and, for example, work-family facilitation, satisfaction and motivation.

2.10 Smart Industry as inspiration for a configurational approach

The previous parts addressed the impact of Smart Industry on job characteristics in isolation. The focus on individual job characteristics and their relations can be considered a common approach since the majority of the studies analysed adopt a universalistic or contingency approach. They either centre on linear relationships or on interactions of contingency variables, rather than a configurational approach which focuses on synergies between interdependent practices into a coherent system _ a bundle of practices that are horizontally and vertically aligned (Delery & Doty, 1996). Yet the Smart Industry pillar network approach or connectivity emphasises the increase in connections between components, whether they be machines, companies and/or humans, within the context of Smart Industry. In other words, a shift is expected from isolated elements to interconnected or networked components. Additionally, Smart Industry itself is characterised by different pillars. Technology, digitisation and connectivity operate together to create a new environment. In contrast to other industrial revolutions, Smart Industry does not stem from a change in a single field (i.e. water/steam power, electrical power and electronics/computers) but from the combination of developments in different areas (e.g. sensor technology, communication technology and data analysis). The Smart Industry phenomenon thus highlights the growing importance of synergies. This emphasis on synergies heightens the interest in the adoption of the configurational approach in the context of job design as well as accentuating it. According to the constructed overview, studies into synergies are hardly present in the literature on job design. The Smart Industry phenomenon, however, places greater emphasis on the issue of synergies, thereby increasing the relevance of the configurational approach. The adoption of a configurational approach regarding job design might thus be a new area of research to be explored.

2.11 Conclusion

In this chapter we have presented an overview of the literature on job design and turned to the challenges that this body of work faces due to Smart Industry. The highlighted challenges are by no means an exhaustive list of the impact of Smart Industry, but are intended to point out the importance of conducting research or raising enquiries towards Smart Industry from a more social perspective, specifically the field of HRM. The topic of job design was adopted as an example to encourage and guide Smart Industry HRM-related research given that this new movement will affect this area of research yet the opportunities that it brings are currently not being taken up by scholars in the field of HRM. As indicated by Vacek (2016, pp. 731-732), “the concept of

'Industry 4.0' is primarily being explored from a technical point of view – robotics, Internet of Things, big data, smart objects, and smart factories. There has been relatively little enquiry into the question of what it means for people and our society on the whole".

2.12 Acknowledgements

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CHAPTER 3

Smart Industry or smart bubbles? A critical analysis of its perceived value

Time box 3:
With the interest in Industry 4.0 really taking off from 2016-2017 onwards, attention towards the unstable understanding of the label also started to grow. In addition it brought the interchangeability and use of various labels into question. Industry 4.0 itself thus required analysis.

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Abstract

Despite the fact that labels such as Smart Industry and Industry 4.0 (terms used to denote the fourth industrial revolution) have become popular topics within academia and in practice, their meaning remains an issue of concern. It's a concern that has drawn the attention of various authors. It is a struggle we engaged in as well – specifically regarding the Dutch Smart Industry label – to aid our aim of assessing whether our call to combine forces can be extended beyond Industry 4.0 and Industrie 4.0. We provide here initial indications of whether there is more unity in meaning and, thus, reasons to take steps toward combining labels. By means of 20 interviews with Dutch Smart Industry experts, a representation of Smart Industry was obtained as understood in the Netherlands. Based on this representation, we examined the extent of overlap between the Dutch Smart Industry label and the general term fourth industrial revolution as well as the Industry 4.0 label as defined by various scholars. Our findings showed that Smart Industry in the Netherlands does not match the denotation of an industrial revolution. Several signals were, however, detected indicating that the content observed under the Dutch Smart Industry label overlaps with what is being presented under the label Industry 4.0. These results reveal that there is indeed more unity in meaning between the various labels that exist and, as such, strengthens our call to combine forces.

3.1 Introduction

The industrial world has never before known this freedom (p. 53) –

New technologies appear; long-established businesses fall on hard times; the economic order is threatened; and society itself experiences drastic challenges to values and standards of behaviour (p. 54) –

There are many unknowns (p. 64)

Although the above quotes from Finkelstein and Newman (1984) address the third industrial revolution, they are just as relevant in the current situation since, once again, we seem to be facing economic upheaval. In other words, following the first three periods of turmoil, it is now being claimed that we find ourselves in a fourth industrial revolution. This revolution triggered the resurfacing of the employment debate again (see e.g.Habraken & Bondarouk, 2017). But it is unique in that it has been announced a priori (Drath & Horch, 2014), and unlike the prior revolutions, there are many different labels used to denote this one. While the third was also known as the computer revolution, examples of labels currently used are Industrie 4.0, Industry 4.0, Smart Industry, integrated industry, advanced manufacturing, or industrial Internet of Things (Davies, 2015; Hermann et al., 2016). The presence of such a diverse set of labels makes it challenging to keep an overview of what has been published, leads to duplicates in the list of key words (e.g. Kang et al., 2016), and risks academic progress by implicitly forcing rediscovery of the wheel. The last point is the most important one since it creates a fragmented field of research. It is understandable if the variety in terms is accompanied by significantly different meanings; if not, this fragmentation is unnecessary and counterproductive for academia. The logic behind the previous sentence highlights an underlying problem of the matter we aim to address. That is, we raise the issue of whether the diversity in labels serves an essential purpose. But the field also struggles with the absence of a clear understanding of these labels, a concern that has recently been addressed by various authors (e.g. Hermann et al., 2016; Reischauer, 2018). The publications by Hermann et al. (2016) and Reischauer (2018) also stress the point we want to emphasize (i.e. does the diversity serve a purpose?). While they each focus on a different label, Industrie 4.0 versus Industry 4.0, it can be concluded from the content of their papers that they consider the other term to be equal to theirs. So why then adopt both, especially in English, and hence international, publications? We would argue – let's combine forces and stop the use of fancy but superfluous words.

The aim of this study is to assess whether the call to combine forces can be extended beyond the labels Industry 4.0 and Industrie 4.0. We do so by focusing on the Smart Industry label. In other words, the value of Smart Industry is assessed by examining the level of overlap with the interchangeable label Industry/Industrie 4.0. This approach was chosen since their descriptions have already been addressed by scholars. A definition of Smart Industry is still required, however. To establish one, we conducted an interview-based study with Smart Industry experts from the Netherlands. We therefore do not claim to offer the definition of Smart Industry. But we provide initial indications of whether there is more unity in meaning and, thus, reasons to take steps toward combining labels. As a result, our research firstly contributes new insights to the present lack of a clear understanding for labels of the fourth industrial revolution. Second, we offer an initial reflection on the necessity of the multitude of terms and resulting fragmentation.

The remainder of this chapter is structured as follows: first, we briefly illustrate the manner in which Smart Industry is depicted in reports from the Dutch Smart Industry team and the confusion that occurs here. Next, the research process is outlined, after which we present the results from interviews conducted with Smart Industry experts. On the basis of these findings, a viewpoint of Smart Industry is developed. Using this perspective, we finally turn to our question of what is the value of Smart Industry.

3.2 Strict technological determinism?

The first official mention of Smart Industry in the Netherlands can be found in the Dutch report from April 2014 (Huizinga et al., 2014). The team behind this report consists of five important parties: the Ministry of Economic Affairs, the Chamber of Commerce (KvK), the Dutch employers' organisation for the technology industry (FME), the Netherlands organisation for applied scientific research (TNO), and the confederation of Netherlands industry and employers (VNO-NCW). In this report, Smart Industry is defined as a strategic vision of the future industry. Such industries are stated to have flexibility in production, being able to (fine)tune to customers' needs, and make use of the entire supply chain for value creation. Subsequently, these outcomes are said to be enabled by a network-centric approach, utilising the value of information, information and communication technology (ICT), and the latest available proven manufacturing techniques. A recap of this description can be found later in the report when it mentions that "Smart Industry – driven by information, digitization, networks, and manufacturing technologies – will improve quality, increase flexibility, increase automation, enhance participation within the value chain and enhance interaction with customers" (Huizinga et al., 2014, p. 25). The above highlights that Smart Industry is seen as a future view of industry stemming from technology. It reflects a cause-and-effect chain in which the origin of the change is viewed from a technological standpoint. In other words, these descriptions as well as descriptions that can be found in other documents adopt a strictly deterministic (Orlikowski, 1992), or technologically imperative, perspective on Smart Industry (Strohmeier, 2009). The report from 2018, for example, states that: “Smart Industry is about future-proof industrial & product systems; these are smart and interconnected and make use of Cyber Physical Systems. Digitisation, connectivity and new manufacturing & product technology are drivers for this” (Ahsmann et al., 2018, p. 9). Though they are scarce, Smart Industry documents also include descriptions that point toward a less strict, deterministic approach: “the previous sections mainly dealt with technologies, but this is too limited. Experience shows that the implementation of technologies for the purpose of benefiting from its opportunities takes special expertise and an innovative attitude” and “Smart Industry is about more than technological developments, ICT and different business models. It is the employee who will have to make a difference and it is important that the employee has the right skills and knowledge” (DutchSmartIndustryTeam, 2015, p. 2; Huizinga et al., 2014, p. 22). They add a moderating effect, specifically the contextual variable ‘skilled workforce’ to the causal chain stated earlier. In doing so, a more moderate deterministic or contingency model is adopted (Orlikowski, 1992; Strohmeier, 2009).

In summary, the first official definition of Smart Industry and even a more recent one from 2018 formulate the label in quite a strictly deterministic manner. However, several notions can be found that depict a different story, and hence nuances are visible that can impact the value of the label. A clearer picture was therefore developed, via interviews, of Smart Industry as understood in the Netherlands.

3.3 Method

3.3.1 Participants and procedure

Along with the program office and the steering committee, the Dutch Smart Industry team consists of a forum group whose members represent a diverse set of sectors and are tasked with creating support, stimulating, connecting, exchanging knowledge, realising togetherness, and making bottlenecks negotiable and solvable (Berentsen et al., 2014). Given this role and the diversity of the members of the Smart Industry forum, we approached them[8], via email, with the question of whether they would like to discuss the meaning of Smart Industry (see Appendix B for details on respondents). The interviews were held between December 2016 and February 2017. After 15 interviews, data saturation started to occur. To achieve full saturation, an additional five interviews were conducted to prevent essential aspects of Smart Industry from being overlooked. Consequently, we conducted 20 interviews in total. Of these participants, 15 were members, or appointed alternatives, of the Smart Industry forum group. Five participants were non-forum members but had been recommended as knowledgeable and actively involved in Smart Industry. In line with the goal of the study, we held the interviews as open conversations and asked respondents how they viewed, defined, and interpreted Smart Industry and/or which aspects they associated with it. Interviews centred on this one single question, which was approached without the use of any pre-set topics in order not to influence the outcomes. Participants were encouraged to explain things more and provide examples if they did not do so themselves. Interviews lasted an average of 47 minutes and were digitally recorded where possible; this was the case for 17 out of the 20 interviews. We transcribed the recorded interviews verbatim (resulting in 106,315 words of transcripts) and emailed them to the participants with an invitation to 'review it and send any comments'. Participants were asked to return any feedback or corrections within two weeks. All edits received were taken into account in the data analysis.

3.3.2 Data analysis

Using Atlas.ti, we first open-coded all transcripts. Chunks of text received codes based on the content that was being discussed in that segment (e.g. background on prior industrial revolutions) or terms that were explicitly stated in that part (e.g. 3D printing, zero defect, big data). In subsequent rounds we only considered pieces of text that contained codes that were of relevance to the research goal of this chapter. Consequently, segments that contained codes addressing, for instance, the background on the three earlier industrial revolutions or insights into the Dutch Smart Industry team were omitted. The

[8] The study is based on the composition of the Smart Industry forum on November 2016

next rounds of analysis were used to develop the remaining codes. This implied that we rephrased code names to fit their content better and bundled codes with similar meanings under a new code (e.g. codes such as internet, IT, digitalisation were combined to form the code 'digitised'). We also created four headings to group several related codes. In doing so, the distinct direction of each code was maintained, compared to having bundled them under a new code. These headings contained codes associated with the expected changes in output of organisations (i.e., products) or the production phase (i.e., production process) and contained organisational departments (i.e., other processes) or types of interactions (i.e., relations) expected to be subject to change. Eventually, 31 codes remained, which we checked and found that they matched the notes taken during the three non-recorded interviews. The analysis of these written notes did not result in the necessity to add new codes to the 31 identified from the transcripts. After the initial open-coding process, we applied axial coding to the 31 codes found. This process resulted in the identification of four distinct categories: intended rationales, key developments, preconditions, and expected impacts. These four categories originated from the examination of the type of words or phrases used within pieces of texts belonging to the 31 codes (see Table 3.1).

Table 3.1 Examples of wording / phrasing and supporting quotes for each of the four identified categories

Category	Notable phrasing	Example quotes
Intended rationales	*The wording or phrasing used express rationales for; e.g.:* so that ; original purpose ; really to ; has to do with ; we need to ; ultimately it is ; we want to maintain ; understand or see that	The original goal was mainly making sure that the Dutch manufacturing industry would not miss the boat given the digitisation of its industry (R4) Thirdly, you see that to remain competitive you have to keep up with current advancements, so as manufacturing companies you have to excel in the area of digitisation, robots, et cetera (R2) We would create a response to Industry 4.0, hence what this would mean for the Netherlands. So that we could present that on the Hannover Messe (R5)
	The wording or phrasing used indicate the essence of; e.g.:	And I think that is also where the breadth comes from, if you look at the Internet of Things – which is really about getting devices connected to the internet – a number of

Key developments	Play important role ; facing us ; introduction of formulated within enumerations ; stated as an antecedent in comprehensive descriptions	technologies immediately come together namely: those devices know something about their current state via sensors so you get a large piece of sensor technology, communication technology is involved since the devices are connected and subsequently there are all sorts of big data and artificial intelligence machine learning aspects involved to, for instance, arrive at new insights on the basis of those data (R9) A few things play an extremely important role within the manufacturing industry. Firstly, are the robots, robotics. Thanks to the use of robots we can: make a production process more flexible and provide higher quality products (R2) Another theme that is facing us, but which has difficulty with finding solid ground, is nanotechnology (R7)
Preconditions	*The wording or phrasing used express required necessities; e.g.:* then at least you know ; must ; will play a role ; condition ; important ; unsustainable	Because you can bring technology in but you will have to get your people on board (R8) The whole security question but also the question of to whom does the data belong to becomes an issue with the increase in digital exchange of information (R17) So there are quite a few boundary/basic conditions like big data security and standardisation (R5)
Expected impacts	*The wording or phrasing used express change; e.g.:* that means that ; consequence of ; affects given comparison then and now ; stated as an outcome in descriptions	That is the result of the IoT, that you can discuss with your customers in a whole different way (R1) If I look at what the digitisation means for us, then firstly it means a great deal for the product we make (R12) Look, Industry 4.0 will affect all production processes and the infrastructure of every business in the Netherlands. And so whether it is about robots, 3D printing or Internet of Things, it affects the core of business processes (R11)

3.4 Findings: The meaning of Smart Industry according to experts

An important element that arose from the interviews was the fact that Smart Industry is seen as a genuinely broad term. Not only was this pointed out by the respondents themselves, '*For starters, Smart Industry is a very broad term, very* *comprehensive*' (R16), it was also evident from the number of identified codes as a result of the question of how respondents viewed, defined, and interpreted Smart Industry and/or which aspects they associated with it. These codes are discussed below under their respective category: intended rationales, key developments, preconditions, and expected impacts (Figure 3.1). We further discovered that though the Dutch Smart Industry platform adopted a narrow interpretation of the term 'industry' to create focus for their platform, the aspects highlighted by the respondents can be considered as being relevant across industries. An example quote to support this statement is: '*In fact, the broadest definition of Smart Industry is how the entire business community gets started with the fourth industrial revolution. Industry is then considered in the broadest sense of the word, so we are talking about hospitals, educational, provincial and municipal institutions, real businesses and business services. Frankly, that is the broad definition which I, not so much the steering committee, but I find important as social development. Eventually, it will impact every profession, industry, company and institution in the Netherlands*' (R11).

3.4.1 Intended rationales

Smart Industry was addressed as a response to Industry 4.0 in the sense that it presented what Industry 4.0 means for the Netherlands. Two broader rationales were 'alerting the industry', the creation of awareness for and acceleration of the changes that are underway and the establishment of support options herein, and 'competitiveness', which referred to the importance of preserving the continued existence of organisations and Dutch welfare. We found these latter two motives to be closely linked to each other; example quotes displaying this link are: '*We have to wake our people up. We have to show them what it all means, what the possibilities, opportunities and threats are. SME's often indicate being busy with their daily work. So we have to indicate that they should think about their future for otherwise their future is suddenly gone, they end up like Kodak*' (R7) and '*Anyway this is the objective, accelerating technological innovation and digitalisation of the industry and increasing competitiveness of the Dutch industry which is crucial for future prosperity and welfare in the Netherlands*' (R8).

3.4.2 Key developments

Four distinct aspects were found, covered by the majority of the interviewees, depicting opportunities that have become available to the industry. One such opportunity that we observed is the continued creation of a digital world (digitised). The importance of this aspect became apparent by the frequent use of the word 'digitisation', but the use of words such as 'internet', 'digital', 'online', and 'electronic' also indicated the shift toward a more digital context. A second direction that we detected was the possibility of establishing connections between devices and/or systems within firms and with external parties worldwide (connected). Respondents again adopted a varied vocabulary to signal the significance of connectivity: Internet of Things or conjugations of the words 'connect', 'link', 'communicate', and 'talk'. The third opportunity highlighted the ability of obtaining and analysing great amounts of real-time data (informed). In other words, there is value in possessing data, and the amount of data we can possess has the potential to increase. For instance, it becomes possible to obtain more information surrounding your product, to be better informed about the status of the production process, or how to get the best results; '*Lelie is able to accurately determine with sensors what food amount, in which composition, for which cow leads to the best milk production*' (R3). The relevance of this development became apparent via the use of the term 'big data' or simply the word 'data/information'. The final aspect depicts the availability of contemporary (non)physical assets (equipped) such as robots, 3D printers, block chain, or nano-technological advancements. A remarkable observation with respect to robots was made since we noticed that different meanings were assigned to this term: (1) an operating robot for production purposes, for example, milking robots in the agricultural sector, (2) moving robots, for example, a robot donkey in the defence industry, (3) cobots, which are collaborative robots that work hand in hand with humans, such as an operation robot, and (4) software, for example, a self-learning program assessing pictures of skin samples and detecting irregularities/dangerous skin situations.

3.4.3 Preconditions

The importance of certain preconditions was identified as a third category that emerged from the interviews. A few respondents addressed the aspects arrangements and legislation, infrastructure, privacy, security, and standardisation. The first condition referred to the importance of establishing arrangements between businesses – respondents, for instance, pointed out the issue of who owns the data, and the deal between Airbnb and the Amsterdam city council – and awareness of legislation-related issues. Issues mentioned included whether an ambulance drone is allowed to land everywhere, when to intervene in autonomous systems, or the denial of recorded data due to differing legislation between countries. The second requisite implied the presence of supporting infrastructure such as the necessity of an excellent digital connection. Third, respondents discussed the importance of focusing on privacy-related issues. Examples that were addressed in relation to this aspect were the discreet handling of personal data by third parties or whether foreign countries receiving data from products that are used here uphold the same cultural value between what is and is not private. The latter two requirements were 'security' and 'standardisation', hence the necessity of cybersecurity and standards for establishing communication between various systems/machines. A condition that was discussed by a greater number of respondents was the importance of addressing social issues[9]. Respondents highlighted the necessity for suitable education, training, and social systems, as well as the importance of people's ability to adapt and maintain their value-adding capability; '*You have to be able to bring your people along with you, and you will also have to keep retraining them because otherwise, with them, you will not be able to survive in the long-term*' (R3). Finally, several respondents referred to the importance of the formation of (cross-sectoral) collaborations and experimental environments. Their presence and importance became apparent via the use of words such as 'share with', 'work together', 'jointly tackle', 'combine forces', or 'Fieldlabs'. The last term was also described as shared facilities, experimental gardens, or learning environments – '*Anyway, it is a place where companies,*

[9] This fact, however, could have been influenced by the authors' more social field of research

knowledge institutions and governments, in a specific area, come together in order to achieve innovation' (R17).

3.4.4 Expected impacts

Expected impacts were identified as the fourth category. Two impacts that respondents covered were 'optimisation' – the realisation of efficiency – and 'reshoring'; a respondent, for instance, mentioned '*It is again worthwhile to bring back production*' (R16). The aspect 'value proposition' covers developments mentioned in this area; answers highlighted the potential creation of new propositions alongside existing ones (e.g. BMW offering their own insurance), the potential establishment of new service-oriented propositions (e.g. new firms offering services related to transcending knowledge build-up), and the rise of new businesses offering existing propositions in a different manner (e.g. Uber, Airbnb).

Next, a number of impacts were grouped under one of the following headings: products, production process, other processes, and relations. Aspects grouped under the heading *products* reflected changes within products. Respondents specifically pointed out the shift toward tailor-made products and the shift from the provision of physical products to services (servicification); an example was selling the service light instead of lamps. Additionally, respondents addressed the general advancement toward smarter, hence more intelligent, complex, autonomous products made, potentially, from materials with new properties. For instance, smart refrigerators or a walker that stops automatically if you are in danger of entering the highway. The second heading, *production process*, contained aspects that reflected changes in firms' production process. Again, two specific developments became evident from the interviews: the shift toward a more flexible production processes and the shift toward greater control of quality. The latter aspect was mainly indicated by the term 'zero defect manufacturing', but one respondent also mentioned that current developments could lead to the method of treatment becoming much more accurate. Respondents further discussed a shift toward managing operations remotely and the continuing conversion to largely automatic operations. Like the previous two headings, the *other processes* label captured changes within processes besides production. While respondents only stated their expectation that the design process is subject to change or briefly highlighted that administration processes are being automated, more detailed answers were found regarding the logistic and maintenance process. Discussed impacts for the logistic process were, for example, the possible introduction of Uber-related concepts or autonomous trucks as well as the disappearance of transportation routes – '*A book publisher does not need to send physical copies to Amazon, but must now have a connection with the printer at Amazon*' (R1). On a more positive note, current developments were addressed as being able to potentially offer solutions to the last mile problem. The answers provided pertaining to the maintenance processes signalled a shift toward a more predictive/condition-based and remote maintenance process. The examples mentioned for the latter case were skyping with a maintenance engineer or having a helpdesk assist someone with the aid of Team Viewer. With respect to the heading *relations*, a distinction could be made between answers that reflected the impact on relations with 'suppliers' – the shift toward more automatic and better aligned supplier networks – or those with 'customers', which implied the shift toward closer relations with them. Example quotes are, respectively: '*That the players in the chain are more aligned to each other*' (R10) and '*So what we see here is that we are addressing and solving certain problems together with the customer*' (R6).

Finally, respondents discussed expected alterations of existing occupations. Although some respondents highlighted the disappearance of certain jobs – for instance, the replacement of cabdrivers and security guards by autonomous cars and robots – most respondents pointed out that jobs will evolve with the present developments. For example, surgeons operating alongside robots or receiving treatment methods from databanks, farmers monitoring the well-being of their crops/animals from a remote data centre, welders who do not physically weld anymore but assess and interpret the output of robots or camera images that they receive, and mechanics who skype with a customer and are faced with new operations due to the emergence of new products. In addition, two respondents addressed the notion of teamwork. They indicated that teamwork, whether with people from various departments internally or with external parties, will be required more frequently in the future. This notion will undoubtedly affect existing jobs.

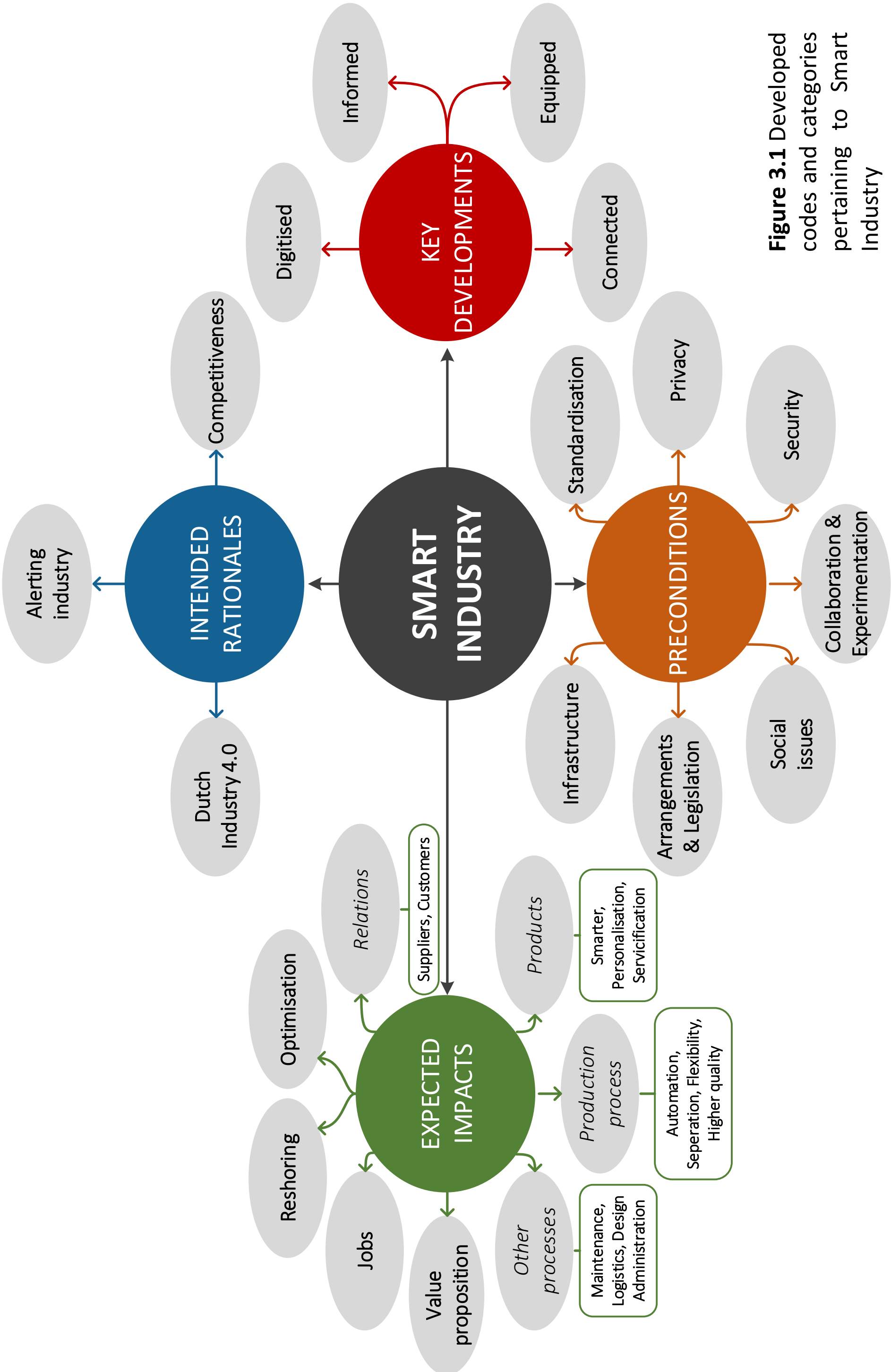

Figure 3.1 Developed codes and categories pertaining to Smart Industry

3.5 A new viewpoint of Smart Industry

The interview results showed that the Smart Industry label is not as straightforward as the initial descriptions led us to believe. In contrast to the technological imperative approach to Smart Industry, our data showed that a broader set of factors needs to be taken into account. We integrated these factors into two distinct components: a communicative bubble and a platform for the multiplicity and complexity of current developments. Both components will be discussed in detail below and result in the development of a new Smart Industry representation.

3.5.1 Communicative bubble

An aspect that stood out involved the notions of alerting industry and competitiveness. Though the descriptions from reports described Smart Industry as 'a strategic vision of the future industry' or being 'about future-proof industrial/product systems', the answers provided by interviewees expressed what is meant by this. In other words, the results depicted the presence of a human desire to establish a means to communicate a sense of importance, specifically toward the manufacturing industry, regarding emerging opportunities or technological developments. It's a tool that could be used to promote innovation. It is assumed that the expectations or visions of smart industries emerged to achieve the desired sense of urgency and promote innovation (i.e., expected impacts like increased flexibility). Consequently, the aim behind the communicative action explains the intense focus on the future visions of industry that can be observed in the descriptions from reports as well as the number of codes found under expected impact.

3.5.2 Platform of current developments

Despite interviewees often speaking of terms such as (big) data, augmented reality, Internet of Things, and block chain, this manner of phrasing current developments signals the existence of a random list of technologies from which we do not become much wiser. The embodiment of main opportunities is therefore taken to a higher level of abstraction. In line with the description of Smart Industry presented in Huizinga et al. (2014), we identified four categories: digitised, connected, informed, and equipped. Yet, in our view the category digitised, the continued creation of a digital world, is imbedded in the other three elements. The emerging connections imply a digital format, the value in information becomes a critical factor because of the large quantities of information available as a result of data which has been transformed or is natively digital, and assets such as augmented reality require a digital component in order to function. Digitised as a stand-alone category is therefore regarded as being redundant. In addition, the establishment of connections is inextricably linked to the collection of information so one could consider combining the categories connected and informed. An explicit distinction between the two categories was made, however, since we want to highlight two specific purposes. One is the creation of new information: in other words, the process of working with the obtained data, analysing it, and seeking the hidden value within it. The other purpose is more efficiency-oriented; the main heroes are the networks, where less to no editing of the information takes place (e.g., indicate location, fit with quality settings). Besides the communicative component, Smart Industry can thus be considered as a platform expressing the three technology-based developmental streams that exist at the moment: (1) the establishment of connections between devices and/or systems within firms and with external parties worldwide, (2) the ability to take more advantage of the value of information via the presence of greater amounts of data, and (3) the availability of contemporary physical and nonphysical assets. Note the omission of the word ‘manufacturing’ in the above enumeration. This was a conscious choice supported by our data and implies that these streams apply everywhere. Additionally, the application of one or more of these streams is restricted by several social and IT-related constraints (see Figure 3.1 and the section ‘Preconditions’), and they are therefore incorporated into the platform component of Smart Industry. In short, this platform component embodies the multiplicity (three streams) and complexity (conditions) of current developments.

3.5.3 Smart Industry

At its basis, the representation of Smart Industry as understood in the Netherlands (Figure 3.2) illustrates the three technology-based developmental streams currently in existence. The communicative bubbles depict the desire to promote innovation. Given our assumption that the intensive focus on future industry visions emerged out of this desire, the bubbles contain examples of these predictions pertaining to smart industries (i.e., the expected impacts). We need to remain critical and think about what happens when we look beyond the communicative bubbles and prick through the commotion of developing awareness and promoting innovation. In essence, the predictions made are not necessarily incorrect. They could stem from current developmental streams, but the extent to which these predictions hold true is uncertain and dependent on the choices organisations make with regard to the opportunities, hence streams, available. Additionally, these choices are influenced by the extent to which existing constraints are dealt with. The right side therefore incorporates the presence of these restrictions via the prison ball and chain symbols. The rest of the right side is kept blank since, to date, we have no precise knowledge on outcomes of the choices made. Outcomes have the potential to alter human actions, positively and negatively, as well as institutional properties like business strategies. We therefore see the communication bubbles, which insist on old fashioned technological imperatives when technology postulates organisational reality, as a step-back in scholarly development discussed in length by academics (e.g. Orlikowski, 1992; Strohmeier, 2009).

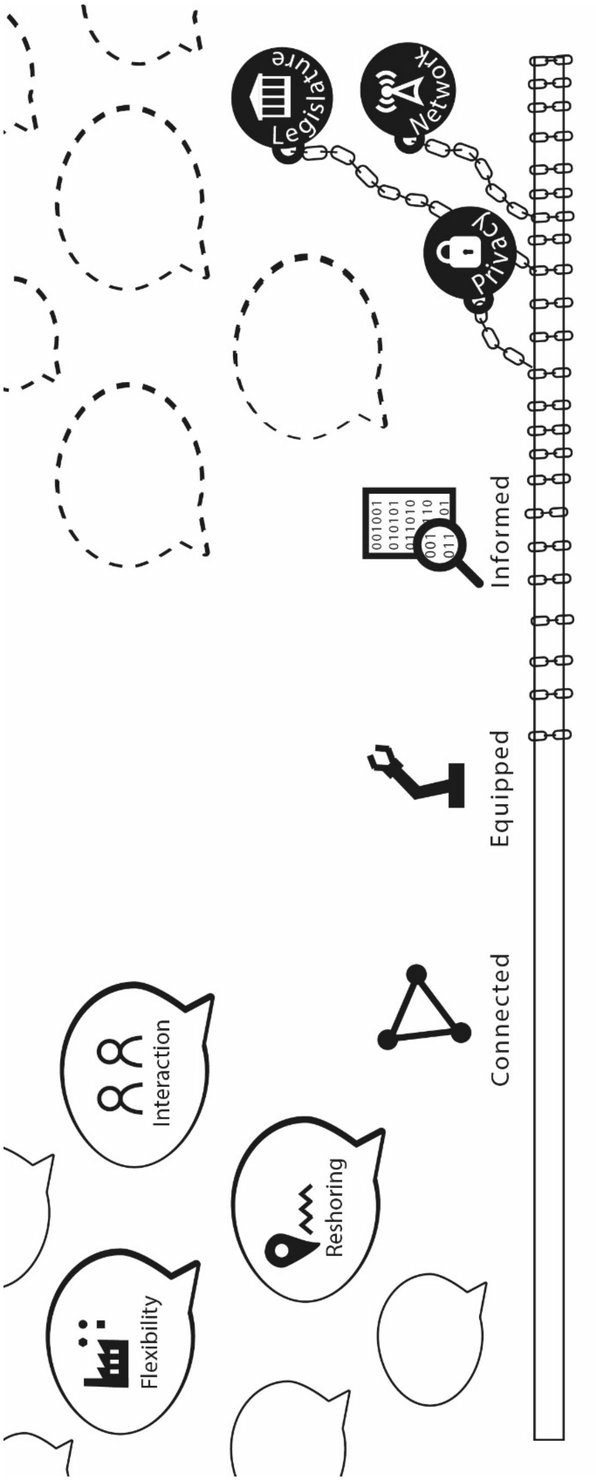

Figure 3.2 Smart Industry

3.6 Assessing the value

3.6.1 Fourth industrial revolution

Along with the other labels, Smart Industry is considered a denotation of the term ‘fourth industrial revolution’. Before turning to the Industry 4.0 label, a brief examination of the link with the term “fourth industrial revolution” should be made. For this, the following definition of an industrial revolution is used: “a rapid major change in an economy (as in England in the late 18th century) marked by the general introduction of power-driven machinery or by an important change in the prevailing types and methods of use of such machines” ("Industrial revolution," n.d.). Specifications regarding the types and methods mentioned are seen as being encapsulated in the addition of the word ‘fourth’. The definition of the fourth industrial revolution adopts a strictly deterministic standpoint, a change that stems from technological developments. This approach matched descriptions found in the Dutch reports, but it does not correspond with the representation of Smart Industry described above. Additionally, the attribution of the term ‘revolution’ to the recent context is questionable since a revolution marks a rapid major change ("Industrial revolution," n.d.), and although it has the potential of being major, the current developments are slow in their implementation. To demonstrate this statement, we briefly highlight some results from a Smart Industry survey conducted in 2015 and 2016 among members of the Dutch Chamber of Commerce research panel[10] (Smetsers & Borst, 2017). We specifically focused on the questions ‘Are you familiar with the term Smart Industry’ and ‘Do you see Smart Industry as an opportunity, a threat or both’ for they represent prerequisites for implementation. In one year’s time, familiarity with the term increased from 10 to 15 percent, and the answer option ‘do not know’ in the second question dropped from 48 to 46 percent. These numbers show that progress is slow as well as low.

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[10] Panel members represent a diverse group with respect to gender, age, sector, and whether they are an independent entrepreneur or part of an SME (up to 249 employees).

3.6.2 Industry 4.0

To assess the value of Smart Industry in comparison to the Industry 4.0 label, we examined whether the components in Figure 3.2 can be found in relation to Industry 4.0. One similarity is the notion of a communicative bubble since the content behind this component is raised by Reischauer (2018) as well as Pfeiffer (2017). Reischauer (2018, p. 26) suggested viewing Industry 4.0 as “policy-driven innovation discourse in manufacturing industries that aims to institutionalise innovation systems that encompass business, academia and politics”, while Pfeiffer (2017, p. 113) mentions that “Industrie 4.0 got its discursive wings not primarily from the rise of new technical possibilities but rather from economic ‘exigencies’ as identified by economic elites”. Our data thus correspond with views of Industry 4.0 being a communicative enabler. A second resemblance exists in the fact that both labels include a set of predictions, or a vision, regarding the manufacturing industry. This is evident from the huge potentials stated in the final report of the German Industry 4.0 working group (Kagermann et al., 2013), a report often cited in papers that look into the Industry 4.0 label. Hermann et al. (2016, p. 3929), for instance, introduces a quote from the German report with the statement “promoters of this idea expect Industrie 4.0 to deliver […]” while Pfeiffer (2017) uses the following introduction “and this future, although driven by technology, magically seems to solve a host of societal problems that were once thought to be insoluble – not only in Germany but across the world”. The frequent mention of security, standards, and infrastructure in papers on Industry 4.0, as well as less often indicated aspects like collaboration or training (Hermann et al., 2016; Kagermann et al., 2013; Pfeiffer, 2017), supports our conclusion that restrictions as a result of social and IT-related constraints are another element that overlaps. The final component of Smart Industry to be discussed are the three technology-based developmental streams. In the report by Kagermann et al. (2013), attention focuses solely on the connectivity stream. Nonetheless, three Industry 4.0 design principles developed by Hermann et al. (2016) – interconnection, information transparency, and technical assistance – overlap with our streams. This indicates that Industry 4.0, in line with our representation of Smart Industry, implies more than establishing networks.

3.6.3 The value of Smart Industry

From the examination of the link with the term ‘fourth industrial revolution’, it can be concluded that the overlapping reference to an industrial revolution does not fit our representation of the Smart Industry label. On this basis, Smart Industry seems to have value. The assessment regarding the Industry 4.0 label, however, shows a different outcome. Several signals were detected indicating that the content observed under the Dutch Smart Industry label overlaps with what is being presented under the Industry 4.0 label. It thus reveals that there is indeed more unity in meaning between the various labels and, as such, this strengthens our call to combine forces and stop the use of fancy but superfluous words. If denotations of the Smart Industry label outside the Netherlands can find themselves in our representation of the term, we see no reason for the retention of the Smart Industry label within academia. The Industry 4.0 label is preferred to Smart Industry since it is already more prevalent in academia – for example, a Web of Science search on Industry 4.0 versus Smart Industry, with time span 2015-2018, results in 2,556 versus 53 records, respectively (on April 30, 2019). Merging Smart Industry into the Industry 4.0 label, instead of the other way around, would thus make more sense. It also ensures that the roots or origin of the label remain preserved since Industry 4.0 looks and sounds closer to Industrie 4.0 than Smart Industry. Note the inclusion of the phrase ‘within academia’. In other words, due to the communicative component, the Smart Industry label has become a highly invested term in the Netherlands (e.g., own logo, national website, documents, and events). The same would likely apply to other country-specific designations adopted for the promotion of this phenomenon. Changing them would therefore be unfeasible. Consequently, the name Smart Industry has value for practice; it is centred on countries, such as the Netherlands, that adopt this term to communicate awareness of current developments and promote innovation.

3.7 Conclusion

3.7.1 Results and limitations

Despite the fact that labels such as Smart Industry and Industry 4.0 have become a popular topic within academia and in practice, their meaning is an issue of concern. Consequently, this struggle has drawn the attention of various authors (e.g. Hermann et al., 2016; Reischauer, 2018). It is a struggle we engaged in as well to aid our aim of assessing whether our call to combine forces can be extended beyond the labels Industry 4.0 and Industrie 4.0. It's an aim that goes much deeper than the aforementioned struggle since it takes the observable diversity of labels into question. By means of 20 interviews with Dutch Smart Industry experts, a representation of Smart Industry as understood in the Netherlands was obtained. Based on this representation, we examined the extent of overlap between the Dutch Smart Industry label and the general term fourth industrial revolution as well as the Industry 4.0 label as defined by various scholars. Our findings show that Smart Industry in the Netherlands does not match the denotation of an industrial revolution. Smart Industry thus holds value over the term fourth industrial revolution. The same, however, does not hold for the Industry 4.0 label. In other words, several signals were detected indicating that the content observed under the Dutch Smart Industry label overlaps with what is being presented under the Industry 4.0 label. Due to our adopted focus, the Dutch Smart Industry label, we cannot extend our conclusion to the Smart Industry label in general. Nonetheless, our findings allow us to address our aim and reveal that there is indeed more unity in meaning between the various labels, which strengthens our call to combine forces.

3.7.2 Implications for practice and academia

Given the aim to promote innovation, the extensive focus in reports from practice on a vision of the future industry that arises out of technological developments makes sense. Words like networks, robots, or increased flexibility sell a story, but they do not help much in representing the direction of the type of choices and the existing restrictions organisations are facing at the moment – for instance, is it beneficial for us to establish connections and should we concentrate on internal networks or also include external networks? Can our infrastructure handle the decisions made? What could we gain by participating in an existing Fieldlab or by collaborating with other parties? Our findings and the representation of Smart Industry presented here, Figure 3.2, aids practice (at least in the Netherlands and likely countries adopting the Industrie/Industry 4.0 label) since they clearly highlight the multiplicity and complexity of current developments. In addition, it depicts the visions of a future industry as what they are – expectations that are dependent on the choices made.

For academia, the results offer the initial evidence for the fact that the diversity in labels does not serve an essential purpose and, subsequently, support our call to combine these labels. Our representation of Smart Industry provides a starting point with respect to the discussion on how to clearly represent the final label the academic community decides to adopt. It highlights that however tempting it is, we as academics should not fall prey to the alluring messages that are part of the communicative bubble but should look past them and not forget the treasure many scholars from management information systems gave us since the late 1990s. In short, rather than returning to a technologically imperative approach of technology – an approach which Orlikowski, back in 1992, already pointed out as furnishing an "incomplete account of technology and its interaction with organisations" (Orlikowski, 1992, p. 400) – current developments should be considered as an interaction between institutional properties, human agents, and technology. The decisions made by organisations as well as their appropriation and modification determine the outcome of technology. This outcome in turn can facilitate or constrain human agents (e.g. speed up work, make it safer or restrict the use of available skills). In addition, the human actions regarding technology are influenced by institutional properties like the state of knowledge about existing opportunities or necessary requirements such as capable infrastructure. Institutional properties in turn are affected by the technological outcome. The latter has the ability to influence operating procedures, communicative patterns, and business strategies. Finally, academia can benefit from our findings by means of the new research questions it generates. From a communicative bubble perspective, we could ask whether it had the intended effect: hence to what extent did it lead to the occurrence of more innovation within the targeted group? What is the network behind this bubble, so who are the initially involved parties, in what way did the network evolve further, and how can the relationship of each party be depicted? And how did the structure of the network affect the level of innovation? Research questions that arise when taking a platform perspective are, for instance, as follows: what choices do organisations make with respect to the three technology-based developmental streams? What factors impact the choices made and in what way are the associated constraints a factor of significance? What are the effects of the implementation of one or more of the developmental streams? This latter question can be considered from a very broad range of perspectives, such as human resource management, logistics, supply chain, a more legal or ethical standpoint, and so forth.

3.8 Acknowledgements

The authors are very thankful to Isabel de Waard for her artwork with regard to Figure 3.2.

CHAPTER 4

Shaking up the status quo? An analysis of developments in the social context of work stemming from Industry 4.0

Time box 4:
As of 2017-2018, a slow shift was visible from a predominating discussion on the continuation of employment to a broader consideration of the influence of Industry 4.0 on work. To add to this body of knowledge, we assessed the developments of an essential yet underexposed domain - the social context.

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Abstract

During the past years, academics have revised their earlier decision to omit the social dimensions of work from work design theory, realising that interpersonal interactions in the work setting are becoming more pervasive. Industry 4.0, however, raises new question marks with respect to this pervasiveness. Terms such as big data, Internet of Things and augmented reality have the potential to lead to shifts in the status quo of the social context of work and implicit issue of thriving. This chapter therefore aims to analyse what developments can be observed with respect to the social context of work as a result of Industry 4.0. Findings from thirteen interviews conducted in four different organisations at two levels suggest that social interactions will not give into digital options. More importantly, they provide a wake-up call regarding the adoption of Industry 4.0 and highlight two ways in which it influences the social context of work and human thriving.

4.1 Introduction

Publication titles such as 'The future of employment: how susceptible are jobs to computerisation' (Frey & Osborne, 2013), 'The future of human work is imagination, creativity and strategy' (Pistrui, 2018) and even well-known sayings like 'Choose a job you love and you will never work a day in your life' highlight the fact that when addressing influences on or consequences of work, we often tend to consider work from a content point of view. Yet the social context which surrounds work – defined as "the interpersonal interactions and relationships that are embedded in and influenced by the jobs, roles, and tasks that employees perform and enact" (Grant & Parker, 2009, p. 322) – plays an essential role as well. Statistical support for this fact can be found in the results of the meta-analysis by Humphrey et al. (2007), which show that social characteristics explain a considerable amount of unique variance in behavioural and attitudinal outcomes beyond the task and knowledge dimensions of work. Academics even revised their earlier decision to omit the social dimensions by recognising that interpersonal interactions embedded in the work setting are increasing in pervasiveness within contemporary organisations (Grant & Parker, 2009; Oldham & Hackman, 2010).

Technological developments – labelled under the heading Industry 4.0 and supplemented by various editions in different countries – facing us at the moment could bring a halt to this observed pervasiveness of social interactions, however. In other words, the far-reaching digitalisation that underlies terms such as big data, Internet of Things and augmented reality has the potential to lead to shifts in the status quo of the social context of work. The huge amounts of data that can now be generated can, for instance, serve as a new source of knowledge for employees. Whether used as is or analysed, this data can be delivered to employees by means of apps, screens or other devices. As a result, employees can obtain performance feedback straight from the data. This would change the way feedback is given and received and puts the use of feedback from others in a new light. Another frequently addressed expectation of Industry 4.0 is the realisation of connected factories. The prediction is that Industry 4.0 will result in far-reaching supply chain cooperation. This signals the introduction of more interaction, but the question is to what extent are those interactions interpersonal; much of this increased interaction could take place digitally via communicating systems/devices. Signs of a lesser extent of social communication are already visible when looking at results from an online survey conducted by Randstad in 2016 among employees[11] in 34 countries. Their data showed that globally, 46% of the respondents agreed that they have fewer personal interactions with their colleagues due to technology. Conversely, the same survey showed that 89% of the participants believed that a face-to-face meeting is the best way to interact with someone (Randstad, 2016). A reasonable question to ask would thus be where are the interpersonal interactions and relationships of work heading to in the context of Industry 4.0? Are we communicating less and less socially or does a smart supply chain create more social interactions with suppliers?

These questions guide our inquiry in this chapter that aims to analyse what developments can be observed with respect to the social context of work as a result of the Industry 4.0 work context. We begin by defining this phenomenon and the adopted interpretation of the social context of work. We then move to the outline of the research process, after which we present the results from the

[11] These employees were: not self-employed, aged between 18 and 65 and worked a min. of 24 h a week.

interviews conducted. Next we discuss academic and practical consequences of the observed developments and provide a synopsis of key insights. Finally, the limitations are addressed, and we end with a brief conclusion.

4.2 Industry 4.0

When reading about the concept Industry 4.0, we cannot escape the connection with the term 'Fourth Industrial Revolution' as it is, quite literally, built into the concept of Industry 4.0. That is, the 4.0 designation signifies it as being the successor to the three earlier industrial revolutions. This connection probably helped ensure the massive interest that now surrounds Industry 4.0. Consider, for instance, the amount of media attention, the number of conferences on this topic as well as the conversations it has sparked within organisations. The popularity of Industry 4.0 did not prevent the emergence of a discussion on its meaning. In other words, the absence of a clear understanding of the label Industry 4.0 is an issue which has been voiced in recent scholarly publications (e.g. Hermann et al., 2016; Liao et al., 2017; Reischauer, 2018). Several papers have even addressed this issue, yet a comparison between, for instance, the work of Hermann et al. (2016), on Industry 4.0 design principles, and the perspective taken by Reischauer (2018) of Industry 4.0 as a policy-driven discourse does not seem to show much unity in how to understand the label. We elaborated on the link between these two seemingly diverse standpoints that can be found in research about Smart Industry, which is the Dutch equivalent to the more common label Industry 4.0 (Habraken & Bondarouk, 2019).

The data in this study, obtained via interviews with Smart Industry experts, led us to develop two distinct components to represent the term Smart Industry: a communicative bubble and a platform for the multiplicity and complexity of current developments. The first component depicts the human desire to create a way to communicate a sense of importance with respect to the observed technological advances, hence to promote innovation. This component overlaps with the viewpoint presented by Reischauer (2018, p. 26) to consider Industry 4.0 as a "broader communicative action that mobilizes actors to innovate collaboratively and that is driven yet not determined by politics". The latter component, a platform for the multiplicity and complexity of current developments, fits with the design principles discussed by Hermann et al. (2016). This component implied that Smart Industry can be considered as a "platform expressing three technology-based developmental streams that exist at the moment: (1) the establishment of connections between devices and/or systems within firms and with external parties worldwide; (2) the ability to take more advantage of the value of information through the presence of greater amounts of data; and (3) the availability of contemporary physical and non-physical assets" (Habraken & Bondarouk, 2019, p. 13). All three streams have a digital aspect imbedded within them. The platform component further entails that the application of these three streams is restricted by several constraints, such as access to required skills or supporting infrastructure. Given the goal of this study, we represent Industry 4.0 only by means of its platform component. In other words, we focus our attention on the three technology-based developmental streams – connected, informed and equipped.

Finally, in general, we adopt the term Industry 4.0 throughout this chapter, but on occasion the label Smart Industry is used since our data were collected in the Netherlands where Industry 4.0 is known as Smart Industry.

4.3 The social context of work

After we clarified our view on Industry 4.0, we turned to the social context of work, a job design category that has had a turbulent history. Job design researchers initially took social dimensions into account, as evident from the assessment of the extent to which jobs involved dealing with others, friendship opportunities, required interaction, interaction opportunities or feedback from others (Hackman & Lawler, 1971; Hackman & Oldham, 1975; Turner & Lawrence, 1965). Yet the job design theory introduced in Hackman and Oldham (1976), the authors omitted any signs of these social dimensions, and they disappeared from general theories and research programmes on job design. Academics today, however, recognise the importance of the interpersonal interactions embedded within the work setting. Oldham and Hackman (2010) even went so far as to state that their earlier judgement call, neglecting the social dimensions of work, was quite short-sighted.

Within this study, we adopt the social work characteristics used by Humphrey et al. (2007) since they are now well-established (see Grant et al., 2011;

Morgeson et al., 2012; Morgeson & Humphrey, 2008). The four social work characteristics that are taken into account are: (1) *feedback from others*, "the extent to which other organisational members provide performance information"; (2) *social support*, "the extent to which a job provides opportunities for getting assistance and advice from either supervisors or co-workers and includes friendship opportunities on the job"; (3) *interaction outside the organisation* is "the extent to which a job requires an incumbent to communicate with people (e.g., suppliers or customers) external to the organization" and (4) *interdependence*, "the extent to which a job is contingent on others' work and other jobs are dependent on the work of the focal job" (Humphrey et al., 2007, p. 1336). By focusing on these four social characteristics, the less prevalent social aspects such as goal interdependence, outcome interdependence or contact with beneficiaries (Grant et al., 2011; Morgeson & Humphrey, 2008) are neglected. Consequently, to prevent another short-sighted judgement call, these dimensions were kept in mind in case they were raised during discussions on interdependence or interaction outside the organisation. Before continuing to the discussion of our method, Fig. 4.1 summarises the above two sections.

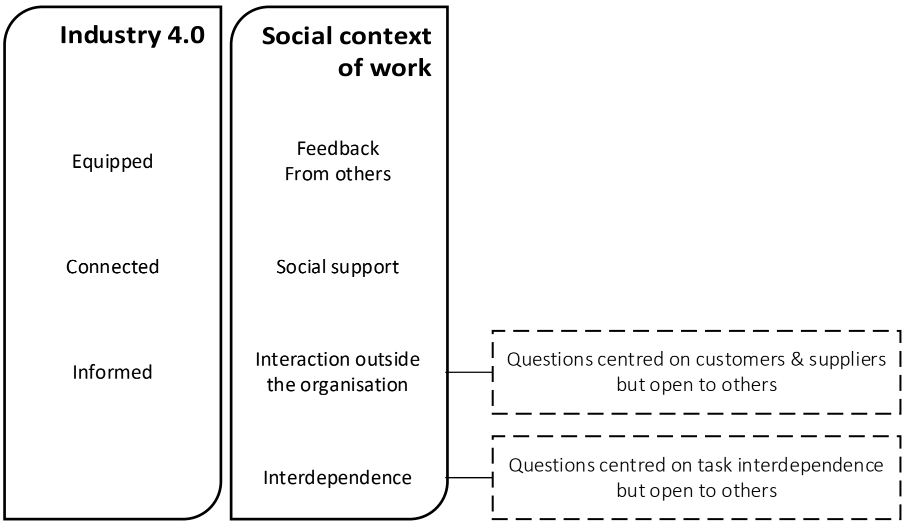

Figure 4.1 Summary of the theoretical part
Based on: Habraken and Bondarouk (2019) and Humphrey, Nahrgang, and Morgeson (2007)

4.4 Method

4.4.1 Procedure

An essential prerequisite for answering our research question was the presence of Industry 4.0 within the organisations in which our interviews would be conducted. Consequently, two sources were used to search for suitable organisations within the Netherlands: the Smart Industry and Human Capital research group at the Saxion University of Applied Sciences and the national Dutch Smart Industry website, specifically their list of ambassadors. Smart Industry ambassadors are companies and institutions that are "ready for the future and actively contribute to the realisation of the Smart Industry action agenda" (Dutch Smart Industry team, n.d.). To ensure consistency among the selected organisations, only those operating in the manufacturing industry were approached. Seven firms were willing to participate in our research. Based on an initial consultation with these companies, four were selected. The selection criteria applied were: the integration of Smart Industry and the availability of appropriate respondents. For instance, one organisation was willing but busy at the time of data collection which led to the unavailability of targeted participants. In addition, another firm stated the use of far-reaching technology, yet this technology was already in use for 20 years and thus not considered smart enough.

The four selected organisations were a company that develops and manufactures mass flow metres, one that produces power management products, and two technical service providers that are active in the manufacturing industry. The interviews within these firms were semi-structured, face-to-face and took place in the summer of 2018. All interviews were digitally recorded and transcribed verbatim. At the end of the interviews, respondents were offered the opportunity to provide feedback on their answers. None of the respondents, however, made use of this possibility. By selecting cases as well as respondents (see participants) in a purposeful manner, by offering respondents the opportunity to offer feedback and by going over transcripts multiple times, within each step, to prevent any oversights as well as incorporate independent analyses by external assessors (see data analysis), we ensured the rigour of our qualitative findings in line with the trustworthiness criteria indicated by Guba (1981).

4.4.2 Participants

Interviewees were selected on the basis of the extent they come into contact with Smart Industry technology. A choice was also made to select respondents from two hierarchical levels – employees and supervisors (supervisors were direct manager of employees). This distinction was made as we wanted to look at the influence of Industry 4.0 on social characteristics of work which encompass the interaction between both levels. In three cases, one manager and three employees were interviewed, while in the remaining case two managers and two employees were approached. Respondents were asked to address changes related to the four social characteristics of work, and thus interviews consisted of the following main topics derived from the literature: feedback from others, social support, interaction outside the organisation and interdependence. Respondents were asked to reflect on the mentioned changes with regard to the role of Smart Industry technology (see Appendix C for the interview protocol).

4.4.3 Data analysis

The analysis of the transcripts took place in several rounds. During the first round, handwritten memos were made for each interview that summarised the social topics being addressed in a few sentences (e.g. importance of collaboration, presence of verbal agreements or increasing customer specifications). This process provided insights into the social aspects being discussed within the interviews. Next, the transcripts were looked at from a more technological point of view. In other words, memos were made that highlighted any technological developments raised in each interview. This ranged from very abstract acknowledgements such as the current complexity of technology to more concrete developments like 3D printers, robots or sensors. Handwritten memos were again used during the third round, but this time the analysis took place at the level of an organisation instead of a specific interview. The aim of this third round was to establish connections between the input from the previous two rounds. Given the complexity of this process, external assessors were contacted to look at the transcripts and offer their opinion on the connections between the mentioned social dimensions and technological developments. Four contacts responded to our request, which resulted in eleven of the thirteen interviews being reviewed by two separate people. As these external assessors did not indicate any surprising findings (i.e. no insights that were not already known), an additional attempt to seek a second assessor for the remaining two interviews was not undertaken. Two final rounds were conducted to combine the previously obtained input at the type of organisation level (technical service provider versus production organisation) and at the overall level. With respect to the last round, a check was performed to determine whether there were any observed findings that could be detected in both types of organisations.

4.5 Findings

4.5.1 External collaboration – customers

One of the most frequently addressed external parties in interviews with both types of organisations was the customer. A particular topic was that a more customer centric approach was being adopted nowadays. Although we could not find a clear link with current technological developments for this observation, the fact that this topic was so prominently visible makes it worth mentioning. A noticeable aspect was that the increase in customer-specific products did not lead to drastic changes for the production organisations. In other words, interviewees stated that contact with the customers was mainly maintained by a sales or service department and by engineers who assisted from a technical standpoint, while staff on the shop floor never communicated with customers. Another interviewee indicated an absence of communication between the production and the service departments. In other words, production was not informed about customer orders that were returned. This is an important statement considering the growing move towards customer-specific production.

The shift to an increasingly customer-centric approach did result in changes to the social context of work within the two technical service providers. Besides technical motives, the possibility to be more customer-oriented was given as a reason for the transition to teams (more details are discussed below). The data from the technical service providers showed that engineers at all levels now have contact with the customer; a project manager (i.e. a senior engineer) is tasked with customer relations and presents a fixed point of contact, while the junior and mid-level engineers discuss technical specifications. One project manager stated, for instance, that '*I am not the translator. We try to put the programmers as close as possible to the customer since customer contact can best be placed with people who know how to make things. We leave a lot to the programmers, who talk with the customer about what they want, and I have a steering and coordinating role*' (R2). This finding could have stemmed from technology since respondents in general addressed the breadth and complexity of technology which fits this change. On the other hand, the previous respondent mentioned that it is not desirable to have the programmers wait patiently to get a project assigned, while a statement from another interviewee signalled that customer preference could be a reason – '*When you ask companies what they prefer, they say that they want a fixed point of contact, but also closer connections with the person who builds the machine*' (R6).

Besides an increase in the extent of contact, one interviewee from a technical service provider highlighted a change in whom you work with regarding customers – '*You see that the client has his own programmer and says we want to develop something together. Then we are not just a supplier, we also provide knowledge to that programmer. You share knowledge, and you work together on the product which is then theirs. You see all kinds of collaborations emerge'* (R4).

4.5.2 External collaboration – suppliers and a lending structure

The communication with suppliers was a topic mentioned less by both the technical service providers and the production organisations. When suppliers were mentioned, it was often in association with common types of interactions such as gaining support, for instance, via email or Microsoft support platforms, or in connection with supply rejections. An exception to the above interactions, which do not reflect Industry 4.0-related developments, is highlighted by the following quote: '*Bosch has obliged their suppliers to place barcodes everywhere so that everything is registered. The entire tracking and tracing process has been optimised in that organisation. Their suppliers must cooperate in this. As a result, you see that cooperation is becoming more and more intensive*' (R4).

Besides customers and suppliers, a new source of external collaboration was observed: '*In the past you sometimes delved into a field of knowledge in order* *to gain some experience, to understand or become better at it. Nowadays that does not work anymore. This is our field and we should not concern ourselves with other aspects. We now seek out a colleague for that, or if we do not have one we find a partner [could be a conculega[12]] that has the knowledge we are after*' (R4[13]). In short, this respondent from a technical service provider expressed the fact that they hire engineers from external organisations, for brief periods such as a day, and also stated that competitors hire his own engineers when specific knowledge is absent. The flexibility of such a construction lies in stark contrast to a statement from one of the production organisations – '*We do not share information with our competitors*' (R10).

4.5.3 Internal collaboration – technical service providers

Within both technical service providers, the most prominent development was the observed shift towards operating in self-steering, multidisciplinary teams on the basis of an agile scrum method. This method entails sprints of approximately three weeks, according to interviewees, and once or twice a week the status of the current sprint is discussed – '*You ask once a week which points are finished, which are not finished and what could have been better or different. For example, we do not have that facility or it does not work; what is the problem so that we can try to solve it*' (R1). The extent of collaboration is further highlighted by the quote: '*We work in a team, a scrum team which is totally non-hierarchical. I would not know who I should see as my boss … it is really collaborative how we decide to address things*' (R5). These indications of collaboration concern how a sprint or the overarching project is tackled. With regard to once individual tasks, an engineer stated that he mostly works independently. This is emphasised by the order of sources that the same respondent mentioned when seeking help: search the Internet, go to a colleague and, if nothing else works, find an external party.

[12] Implies a colleague from a competitor

[13] We are aware that this respondent is used quite often in our discussion of the results. This interviewee however mentioned interesting yet unique insights. Likely as a result of his function and location: 'I started as an ordinary software engineer and quickly became a lead engineer. From 2011, I am a bit of a project leader. Initially, we call our team 'I IT' which stands for industrial IT – not the standard industrial automation but the layer above it. We deliberately called our team Smart Industry because we have a lot to do with that' (R4)

The newness of this multidisciplinary scrum team approach became clear as interviewees mentioned they are heading more towards teams or that they are still working on that transition. In addition, and more importantly, a link with technology was made – '*I think technology has played a very big role in this. The hardest part is always, when do you think you are ready? If you do something straightforward, it is fairly easy to estimate how much work I still have to do. But it is becoming more complex and interconnected and then that question becomes more difficult. In a group you have several people who look at the estimated amount of work and then you notice that the estimate is more accurate. The process and the monitoring of a project can now be done better*' (R2) and '*I think the technology is driving that because you have to be more flexible, and you have to know a lot more things. So that means that you need your colleagues much more. Technology is getting increasingly complex and is broadening … you need the other disciplines in order to offer a total solution to customers*' (R4).

In short, as pointed out by one interviewee, an individualistic approach no longer works in times of Industry 4.0. You have to work together and share knowledge. A self-steering, multidisciplinary team structure thus seems to be the solution for this issue. As a result, the following information came as a surprise – '*The team I work in is composed solely of software engineers. Most of our teams encompass nearly all disciplines, only we as software engineers have our own team. We do this very consciously because technologically wise, it all goes so fast for us. To keep up, we have to share knowledge and we, in turn, deliver our knowledge to all those other teams. That is a bit of a twist*' (R4). It shows the need to find a balance between better information sharing between disciplines, on the one hand, and maintaining the exchange of knowledge with employees of the same discipline on the other.

4.5.4 Internal collaboration – power management production firm

An aspect which stood out in the power management production organisation was the recurring mention of the tiered structure for internal communication used within that specific company. This structure implies a layered approach towards communication: tier 1 is the communication between a supervisor and his/her employees, tier 2 is between supervisors and tier 3 includes the management level. Despite its frequent mention, its newness was questionable and there is no connection with Industry 4.0. One interviewee specifically pointed out that he did not think technology played a role in the emergence of the tiered structure. Respondents also discussed a lot of software applications such as SharePoint or Apex. The introduction of these systems started 18 years ago. Though they signal a digital approach, they are not new advances.

A statement that did display a link with new technology, because it showed overlap with augmented reality possibilities, was: '*What we are looking at now, but that is not there yet, is how can we do things differently on the shop floor? For example, can we work with light or signals instead of work instructions?*' (R11). The respondent indicated that it would likely require a completely different type of employee and that the number of interactions would be reduced, only the tier would be left. In contrast, this organisation's renewed powder-coating installation changed from being automated to now being operated manually. The reason given was rather cryptic, indicating a long payback time of automation with customer demand, but as a result of the change, the interaction surrounding the installation increased – '*Previously it was standing in one place and hanging a plate in the powder coat; simple. Now they are responsible as a team to ensure that steps in the process are done as quickly as possible in succession. That is only possible if they are well attuned to each other*' (R10). It goes to show that in times of Industry 4.0, improvements are not always smart. As a power management company, two interviewees highlighted the smart grid, which can be considered a modern electric power grid infrastructure. The new smart grid project is still a struggle, however, since they would like to incorporate smart elements in their products, but what the customers want is still vague to them.

In summary, it seems that for this organisation, Industry 4.0 has so far mostly resulted in the creation of research projects or a separate department which checks whether there are technologies which they can apply. Consequently, no drastic alterations in the social dimensions of work were found, and the change that was observed surprisingly stemmed from a reduction in technology.

4.5.5 Internal collaboration – mass flow metre production firm

Two developments that stood out in this production case were the introduction of a 3D printer and the new inhouse production of sensors. The 3D printer replaced the procedure of sending designs for tools to Asia, which has led to a quicker and cheaper process. As a result, a tooling engineer signalled the presence of collaboration with the 3D printer operator, R&D and his own colleagues – '*I do not print 3D myself, but I try to contribute ideas. We had a glue tooling but during gluing it was in the way of soldering. So I asked, is it possible to turn it around? With a colleague something new was drawn and printed 3D. Then we tested it, we did think it through? You get to a design in a cheap and fairly quick manner, and we get it checked by people in the department. Ask them what they think of it*' (R9). The importance of collaboration with R&D is also visible for the new inhouse production of sensors – '*We have a new line, the sensor production. That is all new to us. You come to realise that the ideas they have are not that easy to implement. Single pieces are fine, but if you want more than ten, twenty or thirty products a day then some actions become quite difficult to repeat. In that respect you have to communicate a lot with people who are in production, who have a different view on that. Previously, they thought of something, and we just had to make it*' (R8). The difficulty of repeating certain actions likely stems from the fact that sensors have become more complex and contain more electronics. This complexity was also one of the reasons why the organisation decided to bring the sensor production inhouse. A logical consequence of this transition is the dependence created on this department instead of an external supplier that can no longer function as a solid backup – '*The process depends on us in principle, because it is our group that makes the sensors. There is another supplier, but they would have to restart again. Then you have a longer delivery time and that supplier cannot weld*' (R9).

4.6 Discussion

4.6.1 Interaction outside the organisation

The shift in customer contact and the introduction of a lending structure indicate that the engineers in our technical service providers are handling a greater amount of communication with external parties. In addition, the lending structure adds a new party to the standard set of customers and suppliers, while the development in the type of customer that engineers come into contact with (i.e. customer's inhouse programmers) further highlights that there are changes going on with respect to the interactions employees have with people outside the organisation. Another finding was the lack of such advances within the two production cases. Although engineers address technical issues, the data did not show changes in the role of engineers or of the sales/service department. What was observed (no communication between production and service as well as a clear refusal to share information with competitors) goes against Industry 4.0 developments.

In the light of the above, we argue that technical service providers will need to pay attention to the social characteristic interaction outside the organisation. Further research is required to investigate whether this dimension remains the same for production organisations, whether it was specific to our two cases, or if we were simply too early to observe any changes in the external interactions for such organisations. Based on the visible changes within the technical service providers, academics are urged to expand the body of knowledge concerning this dimension since insights into the interaction outside the organisation are currently scarce. The meta-analysis by Humphrey et al. (2007) includes only a single correlation, and articles discussing the future of job design (Oldham & Fried, 2016; Oldham & Hackman, 2010) do not tackle this social characteristic. Stemming from our findings, an interesting research direction would be the inquiry into the types of lending structures that are arising in parallel with Industry 4.0 and the consequences of such structures for employees and organisations.

In the introduction, we pointed out that one of the associated expectations of Industry 4.0 is the realisation of a far-reaching supply chain cooperation. Our data, however, do not present much evidence for this transition. In addition, a critical element underlying this development (Internet of Things, IoT) hardly showed up in our interviews and when it did, it was in relation to exploration – '*What we have done is purely on IoT, we have set up a team that fully focuses on that and initially only pioneers what is out there*' (R4). Consequently, the fulfilment of a smart supply chain might, for now, be a bridge too far. We state 'for now' as the example of Bosch (i.e. their obligation to suppliers to place barcodes everywhere) offers a glimpse of what is possible. At the same time, it highlights that when the expectations raised take off, they will create a large digital data flow. Yet the question of to what extent it influences the external interactions remains; will they decrease, increase or be unaffected? Another point of research that the Bosch example suggests is the impact that the introduction of such a demand creates. In other words, will it strengthen or damage the existing relations and why?

4.6.2 Teams

The technical service providers indicated that in an Industry 4.0 context, where technology is becoming more complex and interconnected and broadening, an individualistic approach to work no longer functions. Both organisations therefore transitioned to self-steering, multidisciplinary teams with a scrum approach. One element of this approach concerns the (bi)weekly stand-up meetings in which progress and existing hurdles are addressed. As a result, social support has become easier and faster since respondents mentioned the reduction in travel time between departments and knowing who possesses which specialism. It is expected that the extent of feedback from others also increased as, firstly, the stand-ups cover which points are finished (or not) and, secondly, the team members have become dependent on each other for the survival of the team – '*If we do not deliver anything, then the budget will be withdrawn and the team will be dissolved*' (R5). In other words, colleagues now have more opportunities and motives to discuss each other's job performance.
With regard to task interdependence, one respondent stated that he is not dependent on others in his work as he mostly works independently. The team approach, however, introduces different types of interdependence. As previously mentioned, they are dependent on each other for the survival of the team and individual tasks at some point have to come together at the team level.

Given the fact that the concept of teams is hardly considered a new phenomenon, the above might not offer huge innovative insights for the technical service providers (and other organisations) or academia. Yet based on the findings, we want to emphasise two aspects. Firstly, the multidimensionality of the interdependence dimension does not receive the credit it deserves. The increasing use of a team structure places more emphasis on varieties in interdependence, and academics are aware of these multiple facets (Grant et al., 2011; Parker et al., 2001). At the same time, the last job design model makes a distinction in autonomy but only focuses on task interdependence (Morgeson et al., 2012). We therefore want to put renewed attention on the message expressed by Grant et al. (2011, p. 441): "it is puzzling that other job characteristics have not been seen as multidimensional when related literatures have highlighted multiple facets". Secondly, one respondent mentioned a social struggle that has arisen as a result of current developments – balancing better information sharing between disciplines on the one hand and maintaining knowledge exchange in the same discipline on the other. Research opportunities are thus reserved for assessing whether this struggle is widely experienced, if the addressed solution can be considered a best practice, or if other methods are adopted.

4.6.3 Physical assets and inhouse production

For both production organisations, the discussions surrounding newly introduced or potential assets stood out with respect to Industry 4.0. One organisation shifted to an inhouse production of its sensors, which led to an increase in feedback from others. For example, designs stemming from R&D are not easily produced in bulk. Solving the problem without R&D, as used to be the usual procedure, is apparently not an option here. It resulted in communication, or co-design, between the sensor production and R&D regarding the output of the latter. The 3D printer introduced by the same organisation resulted in an increase in social support since it offered a cheap and quick manner for designing things. Adjustments are therefore easier to implement, and requesting support from others thus becomes more accessible. A reduction in interdependence was not ensured, however, since employees do not print items themselves, so there was only a shift from an external supplier to the internal 3D printer operator. A similar shift was observed for sensor production. The level of interdependence did change for employees of the renewed powder-coating installation. Finally, the potential application of light or other signals as a means of work instructions is expected to drastically alter social interactions. It would likely simplify tasks to such an extent that most types of interactions will become superfluous, hence the comment, '*Only the tier will be left*' (R11).

Production organisations are therefore alerted to keep social influences in mind when introducing such developments. In other words, a reduction in social interactions could be a welcoming solution for certain people (e.g. those with a distance to the labour market), but they also need to be the target group. The decrease in technology observed in one of our cases also creates future research opportunities. A question that could be asked is if it represents the presence of a counter-movement, or whether the viewpoint of this organisation should be considered an exception that will cause problems in the long term? (e.g. '*We have many manual activities. That has to do with the numbers and the customer-specific parts. That is why we are still here for if everything is completely automated, you can go to, for example, Romania, because then it will cost nothing*'; R10).

4.6.4 From social to digital?

The Internet, email, WhatsApp groups, video meetings, SharePoint and software applications such as Apex are a few of the digital tools that were mentioned during interviews with both types of organisations. This highlights the embeddedness of a digital way of interacting in our current way of working. Yet none of the examples are communication methods based on the far-reaching digitalisation that underlies terms like big data, Internet of Things and augmented reality; hence, they do not reflect Industry 4.0. Consequently, we could raise the point that we were simply too early to detect a growing digital invasion. However, the acknowledgement of stand-up, sprint or tier meetings, travelling between locations (in one case, collaboration needs to take place between two different locations which is facilitated by means of a video connection, yet it was stressed that being able to see, smell and feel each other works the best) as well as a supervisor's indication of wanting daily contact with his employees stresses that digital contact has not, and will likely never, fully take over. In other words, social and digital means of contact are expected to coexist since they seem to be used for different reasons. For instance, quick solutions or minimising the interruption of flow versus discussions, not alienate from each other or a lack of digital options. We assume that this dichotomy will persist in an Industry 4.0 context. Additional support for the preservation of social contact can be found in the following quote: '*With the what, data often* *does not lie. But you also have a how. How do people do that? How are people doing? Then you come more towards the soft side. Passion is sometimes very difficult to make smart*' (R10).

4.7 Synopsis

Industry 4.0 is represented by means of the three technology-based developmental streams that currently exist: *connected*, establishment of connections between devices and/or systems within firms and with external parties; *informed*, ability to take greater advantage of the value of information; and *equipped*, availability of contemporary (non)physical assets (Habraken & Bondarouk, 2019). The respondents' acknowledgement of the complexity of technology and the observed presence of an exploration stage regarding the first two streams highlighted that the adoption of these streams is not that straightforward. Nonetheless, the perceived complexity has already led to the following findings:

- Extent of interaction with customers increased for the technical service providers. Not only are their engineers more in contact with the customers, the type of customers they deal with has also expanded. It raises the need for organisations to pay attention to, and for academia to conduct more research into the effects of the characteristic interactions outside the organisation

- A new external party was observed—a hired knowledge expert stemming from the lending structure. This also creates an additional source of social support for the technical service providers. Apart from gaining assistance or advice from supervisors or co-workers, external sources such as competitors are contacted for help. Given its newness, this lending structure creates interesting research possibilities which could also assist practice with identified challenges related to this structure

- Both technical service providers transitioned to operating in self-steering, multidisciplinary teams. This transition subsequently led to an increase in social support, and we also expect a growth in the extent of feedback from others given increased team dependency and the stand-up meetings. Though teams are a known structure, findings raise the issue of multidimensionality of characteristics and an apparent struggle when it comes to team formation

- o A transition to inhouse production of sensors was observed in one of the production organisations, which led to an increase in feedback from others and a shift in the source of interdependence

Changes to the social work context were also found as a result of the presence of physical assets. The 3D printer within one production organisation resulted in an increase in social support and a shift in the source of interdependence, while the idea of using lights or other signals as work instructions by the other production organisation was expected to reduce the extent of social interaction in general. The direction of intensity change thus varies per technology and means of adoption. Organisations are therefore advised to take the social aspects into consideration during the decision process.

The above insights are represented in Fig. 4.2. It depicts Industry 4.0 with the observed abstract terms and the three technology-based developmental streams that underlie them. Each specific stream is represented by more or less spikes depending on the observed implementation level. Industry 4.0, in turn, was found to influence the social context of work in two ways: (1) by altering the intensity or source of current social work characteristics and (2) by introducing new or emphasising known structures. Finally, the vertical arrow indicates that the bottom structures can cause changes to the intensity level.

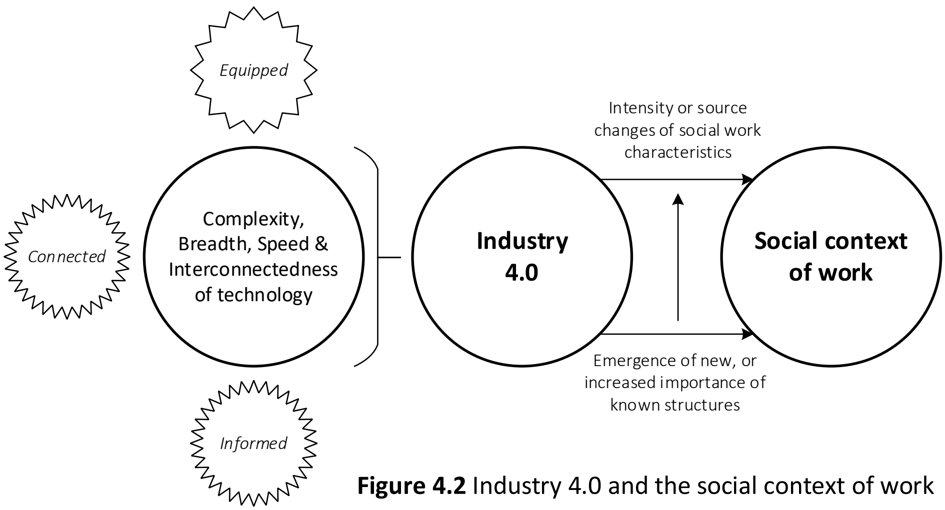

Figure 4.2 Industry 4.0 and the social context of work

4.8 Limitations

Given the aim of our study, we have to point out that despite our careful selection, Industry 4.0 still seems to be more a subject of research than reality. This finding fits our opinion that Industry 4.0 is not the rapid major change that the definition of industrial revolution defines it to be (Habraken & Bondarouk, 2019). Yet, it poses a limitation to the current study. Another limitation is the specific focus on the manufacturing industry since Industry 4.0 is also applicable to sectors such as healthcare or transport. We expect that the presence of alterations in the intensity of current social work characteristics is applicable to other sectors. For instance, with the introduction of patient coaching platforms, an increase in interaction between physicians, nurses and patients could be assumed.

4.9 Conclusion

In sum, three developments concerning the link between Industry 4.0 and the social context of work can be found as well as one general remark. Beginning with the latter, the low presence of Industry 4.0 in the selected cases should in our view be classified as a valuable finding as well as a limitation. It stresses that more attention needs to go to the implementation of Industry 4.0. Turning to the three developments, we firstly expect that social and digital means of interaction will coexist in an Industry 4.0 context. The second and third developments highlight two ways in which Industry 4.0 was found to influence the social context of work: altering the intensity/source of current social work characteristics *and* introducing new/emphasising known structures.

CHAPTER 5

Using a decision-making lens towards the application of Industry 4.0

Time box 5:
By 2019, the passing of time provided room for raised expectations to take form. But, in contrast to the extent of communication, the realisation of Industry 4.0 was found to be lagging behind. With a prominent presence aiding inquiries into its effects, our focus turned to the issue of a lagging adoption of Industry 4.0.

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Abstract

Compared to the extent of communication on Industry 4.0, the adoption of the phenomenon appears to be lagging behind. The dominating approach to this issue is a focus on the barriers to Industry 4.0 implementation. The lag could also be attributed to the decision-making phase that precedes implementation. Consequently, this paper aims to illustrate the complexity and importance of the decision-making phase surrounding Industry 4.0, by developing an Industry 4.0 strategic decision-making typology. The layout of this framework stems from insights from institutional theory and work on strategic management and decision-making. This creates four quadrants depicting potential motives to opt for Industry 4.0. The empirical content for this framework is based on data from eight cases selected from the websites of the Dutch national platform and a Dutch regional platform for Industry 4.0. Based on a cross-case analysis, it was found that it is not just intensive rivalry or large customer demands that are relevant. In addition, the complexity and importance of the decision-making process are emphasized by the fact that the quadrants play two different roles in the process of deciding to opt for Industry 4.0: prime movers and necessary facilitators.

5.1 Introduction

It no longer needs to be explained that in recent years, Industry 4.0 – understood here as the three technology-based developmental streams currently in existence: connected, equipped and informed (Habraken & Bondarouk, 2019) – has become a frequently discussed topic. So much so that it creates a certain expectation with regard to the visibility of Industry 4.0 in practice, especially since one aspect of the phenomenon is its function as a communicative enabler, i.e. a tool to promote innovation (Habraken & Bondarouk, 2019). Yet, in contrast to the above expectation, the implementation of Industry 4.0 seems to be lagging behind. In other words, Industry 4.0 is less prominent in practice compared to its written 'construction'. This assertion was noticeable in our recent publication (Habraken, Bondarouk, & Hoffmann, 2019) and is also reflected in the following quotes: "there is hardly any use of truly innovative technology at the moment" (Freese et al., 2018, p. 5) and "in our view the rate of implementation within businesses needs to be stepped up" (Huizinga et al., 2018, p. 24). Müller, Kiel, et al. (2018) came to a similar conclusion, highlighting that "research and practice disclose a reluctant and slow realisation of this novel manufacturing paradigm" (Müller, Kiel, et al., 2018, p. 2). These authors continued by ascribing it to "unclear opportunities and challenges perceived by industrial manufacturers" (Müller, Kiel, et al., 2018, p. 2). This opinion seems to be partially shared by other scholars, when considering the recent attention paid to the challenges to Industry 4.0 implementation. These challenges were also addressed by Orzes et al. (2018) and Moktadir, Ali, Kusi-Sarpong, and Shaikh (2018) by means of a literature review combined with either focus groups or feedback from industrial managers.

The attention paid to Industry 4.0 challenges is mainly focused on realisation-oriented factors. Observed barriers relate to categories such as: *financial* (e.g. high investment), *technical* (e.g. difficult compatibility), *legal* (e.g. data insecurity), *cultural* (e.g. acceptance, skills, support problems) and *implemental* (e.g. no methodical approach) (Moktadir et al., 2018; Orzes et al., 2018)[14]. But the issue of a lagging presence of the phenomenon could also be attributed to the decision-making phase that precedes implementation. In other words, to establish Industry 4.0, organisations require more than the practical elements for its realisation. There should also be a motive that substantiates the implementation phase. This perspective is supported by findings like "keeps working on the old-fashioned way since this is their current competitive advantage" or "we distinguish between two categories of motives: internal ones derived from perceived market opportunities and external ones, derived from demands exercised by large customers" (Engelbertink & Woudstra, 2017, p. 12; Müller, Buliga, & Voigt, 2018, p. 9). In addition, the communicated opportunities can be considered a publicity-driven motive, hence Industry 4.0 is depicted and perceived as creating benefits for employees, the environment and the operational process as well as offering new business possibilities (e.g. Huizinga et al., 2014; Kagermann et al., 2013; Müller, Kiel, et al., 2018).

Taken together, we notice that the dominating perspective regarding the lagging adoption of Industry 4.0 is aimed at issues related to its implementation.

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[14] Challenges mentioned by Müller, Kiel, et al. (2018) are not included since the paper does not provide empirical data regarding their specific items, which is an issue due to the fact that the overarching categories contain items of varying topics (i.e. high costs with too little standardisation, or loss of market niche with dependency on others).

At the same time, there are statements highlighting that the decision-making phase could also be a contributing factor. Nevertheless, these statements offer few and fragmented insights into the alternative, decision-related, viewpoint. In order to address this shortcoming, that is to illustrate the complexity and importance of the decision-making phase surrounding Industry 4.0, this paper offers an integrated perspective on the motives underlying the decision to opt for Industry 4.0. We do so by developing an Industry 4.0 strategic decision-making (SDM) typology, using insights from institutional theory and work on strategic management and decision-making. This typology is based on the premise that the type of incentive underlying an Industry 4.0 decision will influence its implementation process. For instance, a decision based on a power-oriented call to act on the proposed opportunities (i.e. decision from influential organisational member(s)) might make less use of employee participation compared to a decision based on a competition-related necessity. If so, the latter will probably face fewer employee acceptance issues. The constructed framework can thus be used as an initial means to address the relevance of the identified challenges mentioned above. Finally, the paper presents an instrument to understand why organisations differ in the manner in which Industry 4.0 is shaped in practice.

In the next section, the adopted theories are discussed, which leads to the layout for the Industry 4.0 SDM typology framework being developed. Subsequently, the method used and results for each specific case are presented. Finally, the paper presents a cross-case analysis of the results and concludes with a discussion section that also addresses limitations and future research directions.

5.2 The basis of the framework

In building the layout of the framework used in this paper, we draw from the following three bodies of literature: strategic management, institutional theory and decision-making. They were chosen since they offer relevant, yet distinct views of the reasons behind Industry 4.0 SDM.

The strategic management literature provides two rationally oriented perspectives. The attempts to understand the sources behind firms’ sustained competitive advantage have led to an approach that emphasizes the role of the firm's environment (i.e. external focus) and one that derives its reasoning from within the firm (i.e. internal focus). Effort is thus directed either towards the analysis of opportunities and threats that arise from a firm's environment *or* towards an organisation's own strengths and weaknesses (Barney, 1991). A classic but still prevalent model to evaluate the environmental opportunities and threats is the five forces model developed by Porter (1979). It highlights that besides the jockeying among direct competitors, competition stems from four more sources: threat of new entrants, threat of substitutes, as well as the power of buyers and suppliers (Porter, 1979). Knowledge of the state of these five forces, or an industries structure, in turn aids managers with identifying possible or necessary strategic actions (Porter, 2008). Opting for Industry 4.0 might be the result of such a strategic action. Assessing the strengths and weaknesses within an organisation, on the other hand, is rooted in the resource-based view. Here, the point of reference for understanding organisational success involves the firm's resources, which include "all of the financial, physical, human and organisational assets used by a firm to develop, manufacture and deliver products or services to its customers" (Barney, 1995, p. 50). Gaining a sustainable competitive advantage is realised through the possession of resources that are valuable, rare, imperfectly imitable, and have no strategically equivalent substitutes (Barney, 1991). This enumeration was later slightly adjusted, with substitution being incorporated in the imitability component and the addition of the factor 'organisation': whether a firm is organised to capture the full competitive potential of its resources (Barney, 1995). The notion of valuable, however, is of specific interest here since it is linked to a firm's ability to recognise and/or react to fundamental changes, and thus new opportunities or threats. In other words, the availability of valuable resources allows an organisation to move away from a competitively disadvantaged position. Consequently, it is considered a factor that can play a role in why an organisation opted for Industry 4.0. From the strategic management literature, two motives that affect an organisation's decision to opt for Industry 4.0 are identified: the influence of external competitive forces and the possession of valuable resources.

These two motives, however, assume that organisations act out of rational considerations, but this is not always the case. The incentives that are discussed next depict two non-rational or intuition-based perspectives that underlie the decisions that organisations make. Firstly, we address the mimetic mechanism which is founded in institutional theory. It refers to the imitation of practices performed or suggested by other organisations, hence modelling, as a result of uncertainty (DiMaggio & Powell, 1983). Industry 4.0 is a complex phenomenon for which no universal definition exists, but it is also a trending concept that is surrounded by much promotional communication from influential sources. The Dutch Industry 4.0 platform, for instance, consists of sources like the Ministry of Economic Affairs, a research institution and employers' organisations. Industry 4.0 can therefore be considered a popular phenomenon associated with uncertainty, making it a suitable candidate for the mimetic mechanism. The explicit form in particular is highlighted by DiMaggio and Powell (1983) as stemming from organisations such as industry trade associations. Put differently, the decision to opt for Industry 4.0 might also arise out of a mimetic behaviour such as the modelling of actions proposed by influential parties.

The second intuition-based perspective is derived from the decision-making literature. It emphasises that there are also subjective factors affecting decision-making. One such factor involves values or preferences held by an individual or group, which make "some courses of action more desirable than others, or some outcomes more desirable than others" (Beyer, 1981, p.167). Technological development, as depicted by Rogers (1983) innovation adoption curve, is valued differently by people and may thus influence the Industry 4.0 decision. It is also essential, however, to consider the position of the value holder. In other words, the values or preferences needs to be rooted in those authorised to make the decision. Therefore, Beyer (1981, p.187) not only indicates that "people behave in accordance with their own values" but also "in accordance with the values of powerful superiors". The decision to opt for Industry 4.0 could thus also stem from values held by a powerful decision maker(s).

The above results are summarised in a framework that consists of an axis that distinguishes between an internal or external focus and one that differentiates between the use of a rational versus intuition-based perspective. Together, they create the following four motives that can play a role in an organisation's decision to opt for Industry 4.0: values of decision-makers, valuable resources, mimetic behaviour and external competitive forces. Having developed the skeleton of the framework (Figure 5.1), we now turn to the empirical field to unfold it.

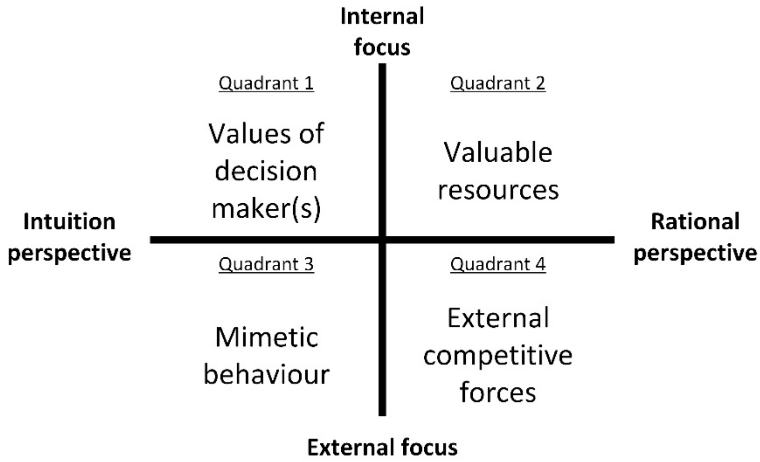


Figure 5.1 Industry 4.0 strategic decision-making typology

5.3 Method

5.3.1 Case selection and procedure

For our case selection and data gathering, we made use of a specific part of the Dutch national platform and the eastern Dutch regional platform for Industry 4.0 (or Smart Industry in the Netherlands). The websites of both platforms are openly accessible (i.e. smartindustry.nl & smartindustryoost.nl). On their website, the platforms feature a section pertaining to 'smart companies'. It presents a set of organisations that are ahead in the adoption of Industry 4.0, and in so doing they form an ideal initial case set[15]. Additionally, for each of the stated cases, the websites provided intriguing data in the form of interview transcripts, text based on conducted interviews and/or video material.

Before turning to the assessment of the data, a first selection was based on whether the cases were a provider or a user of Industry 4.0. Given that our research is aimed at motives underlying the decision to opt for Industry 4.0, the cases that were categorised as providers – for instance, a software service provider, data analyst or robot developer – were eliminated from our focus. This led to the deletion of 12 cases from the total of 34 unique cases (three firms

[15] The starting pool is based on the available cases as presented in June 2019

were visible on both platforms). In addition, seven cases were dismissed as they represented a Fieldlab/test facility or a network and not a single organisation. The criteria of a single organisation was chosen in order to maintain the focus on actual Industry 4.0 considerations, compared to the experimental settings linked to the Fieldlabs, for instance. Next, the available data from the remaining cases were analysed, leading to the deletion of ten more cases. The text for these cases focused purely on technological aspects and/or provided no detailed insights into the reasoning behind the adoption of Industry 4.0 (the mention of, for instance, time/cost savings or increased production was insufficient to retain a case). However, to prevent omitting interesting cases from our line of sight, a Google search query was conducted. It contained the respective firm name and Smart Industry. Among the hits obtained, we specifically looked for other sources that offered interview data with members of the respective organisation; the latter was used to guarantee the content. This revealed hits for two companies: De Cromvoirtse and GS Metaal. Apart from these two outcomes, the search query yielded a grant application for the organisation Kornelis Caps and Closures. Given the usefulness of the presented data and the source of this hit (national government), an exception from the interview layout was made. As a result, they were re-introduced, leaving eight remaining cases.

For these cases, the firms' websites were accessed to gain additional data about the organisation itself, the technology adopted and aspects related to decision-making. The website of Bruil, for instance, offered extra details about why they made the transition, and the website of Van Raam Rijwielen contained another relevant video regarding their new factory. Finally, to build up the available data for these cases, the Google search query was applied again. This resulted in additional data for Aebi Schmidt and Kornelis Caps and Closures. The identified article for the latter organisation provided extra content on Industry 4.0 and could therefore not be used in the above-mentioned re-inclusion processes. Table 5.1 presents company- and interview-related details.

Table 5.1 Company and interview details for each case

COMPANY DETAILS			INTERVIEW DETAILS	
Name	**Number of employees**	**Activities**	**Interviewee**	**Date**
Aebi Schmidt; NLD, Holten	Approx. 200	Main focus is development and production of winter maintenance vehicles	One or combination of: Director production Holten, Director NLD & Belgium, Prof. at TU/e	NP - unknown[1] RP - 29.3.17[1] O - 10.10.17
Bruil	Approx. 400	Concrete factory	Market & Innovation manager	RP - 1.12.16
De Cromvoirtse	Approx. 60	Supplier of sheet metal; cutting, sawing, edging	One of the owners	NP - unknown O - 23.11.15
GS Metaal	Approx. 40	Metalworking company, specialised in laser cutting, edging, welding	One or both directors	NP - unknown O - 7.5.18
House of Blue Jeans[2]	?	Clothing store	Owner	NP - unknown
Itter	Approx. 40	Core competence machining aluminium	One or both owners	NP - unknown RP - 29.3.18
Kornelis Caps & Closures	Approx. 50	Develops and produces caps, lids and closures	One or combination of: Production manager new construction, Director of GotoGemba	RP - 30.1.18 O - 23.11.17
Van Raam Rijwielen	Approx. 130	Bicycle manufacturer of adapted bicycles	Financial / HR director	NP-vid 25.1.17 RP - 18.10.17

Abbreviations: NLD is the Netherlands; *NP* is the Dutch national platform; *RP* is the eastern regional platform; *O* are the other interview sources; *TU/e* stands for the Eindhoven University of Technology; and *vid* means video

[1] Both sources contain nearly identical texts

[2] The Facebook page of this company can be considered as the firm's website

5.3.2 Data analysis

For each case, the available data (Appendix D) were grouped based upon the extent that it provided knowledge about one of the following categories: (1) the manner in which Industry 4.0 was shaped; (2) the presence of relevant resources; (3) the presence of essential external influencers; (4) competition, values or other reasons for Industry 4.0 adoption; and (5) statements pertaining to the organisation's goal. Data on topics linked to the implementation process of Industry 4.0, such as employee participation, financial subsidy received or pilot projects, were thus not included in the scope of this study.

The first category provided specifics regarding the application of Industry 4.0, while the fifth category offered an insight into the general goal of the organisation. The remaining categories stemmed from the literature used to build the framework as discussed above. Category two reflected the resource-based perspective while category three aimed to cover the mimetic mechanism. Category four focused on the forces of competition and the decision-makers' values but also allowed potential new observations. The identification of information pertaining to these five categories took place over several rounds and was aided by the development of a flow chart for each case (Appendix E). The creation of these flow charts helped with the establishment of a clear overview or representation of each specific situation. Based on the information gathered for the categories and the constructed flow charts, case-specific frameworks were built (Appendix E) which functioned as input for the construction of a cross-case framework; see the cross-case analysis section for more details.

5.4. Individual case analysis

5.4.1 Aebi Schmidt, the Netherlands

For Aebi Schmidt, the highlighted Industry 4.0 direction was obtaining knowledge regarding the deployment of the vehicles by their clients. Consequently, the firm equipped their spreaders with a controller that offers up-to-date insights – on performance aspects such as spreading dosage and on service aspects like its usage in hours or kilometres driven – made accessible via a web application.

The need for the indicated knowledge base stems from a concept associated with Industry 4.0: servitization. In other words, they are becoming a caregiver with integrated solutions. The organisation even defined a new mission: “improve customer performance and become a supplier of ‘clean road’ solutions” (Link Magazine, 2017). The focus on servitization has been found to have several causes. One can be traced to the fact that servitization is a part of the Industry 4.0 promotion (see e.g. Ahsmann et al., 2018), as evident from the following quote, “*In so doing we respond to the megatrends: solutions instead of products, availability instead of ownership*” (Link Magazine, 2017). Obtained data further suggested that the observed transition is connected to (European) regulations surrounding the customers. In other words, the customer base of firms like Aebi Schmidt require a unique sales approach due to the presence of mandatory tenders. The presence of tenders creates a specific form of competition in which, according to the Dutch public procurement expertise centre, the focus is often still on “following tendering rules and opting for the lowest price” (PIANOO, 2019). It explains the statement that signaled Aebi Schmidt’s re-evaluation of what their customers would want to pay for. “Traditionally, making the best machines is the aim of many machine builders. But do customers want to pay for this? After all, it is not about the quality of the machines, but about the results they achieve” (Link Magazine, 2017) and “*In the end, they find a clean, safe road in winter conditions much more important than having a spreader or sprayer*” (Boost_AS, 2017).

Internal factors that seem to have contributed to the Industry 4.0 transition taken by Aebi Schmidt are, firstly, their central question of ‘can it be done differently and (as a result) better?’ which they uphold in everything they do. An additional trigger is that Aebi Schmidt had already introduced modularisation. This concept is emphasised as an essential ingredient for servitization, along with access to data. The relevance of modularisation, and the necessity to do more, are highlighted by the following. “*We cannot use the fact that our machines have a modular structure as a sales argument. But we can offer to unburden the customer in their maintenance, …, which in turn is due to this modularisation*” (Link Magazine, 2017).

Framing these outcomes in line with the constructed framework results in the following conclusions. The decision to gather knowledge on the deployment of the vehicles by their clients – for the move towards servitization – was influenced by the existence of a price-oriented competition (an external competitive force) that originates in the mandatory tenders. The embedding of the price competition in these tenders makes it impossible for Aebi Schmidt to change the type of competition. Competing with a new form of price reduction, hence servitization, thus becomes a logical step. The recognition and assumed necessity for servitization were likely encouraged by the amount of communication stemming from the Dutch Industry 4.0 platform. It is a trending concept which is promoted by influential parties. Consequently, some presence of mimetic behaviour can be observed. Finally, the culture and the presence of modularisation are viewed as valuable resources. They allowed the organisation to recognise and act on a new opportunity.

5.4.2 Bruil

The dominant Industry 4.0 direction mentioned for Bruil is their decision to adopt 3D technology, hence to start printing concrete. The consequences of this decision not only involved the self-developed 3D concrete printer with which they wish to build their own stamp on 3D printing. "Our 3D printer is currently delivering comparable results to other well-known 3D concrete printers in the world. But the bar is slightly higher. Within a few months we expect to be able to show the first results of our own vision on this topic" (News, November 2015). It also ensured that the organisation had software developed in order to convert the 3D models of architects into print paths – "*Today's architect no longer designs, but programs. What is easier than sending digital designs directly to a concrete printer that prints the designs immediately?*" (Boost_B, 2017). In addition, Bruil is currently building a specific prefab printing factory to enable a bigger approach (e.g. larger and mobile printer) to their 3D printing.

The initiation for adopting 3D printing technology can be traced back to the reconsideration of the organisation's strategy, in 2014. Conclusions that were drawn from this reconsideration were: some of their products were not distinctive enough, the main focus in recent years had been on reducing losses, and the insight that they had to innovate in order to escape the stranglehold of the market, aimed only at price competition. The highlighted market situation can be traced back to the crisis that started in 2008 as evident from the following quote. "*Ultimately, everyone can make concrete. During the crisis we could, therefore, only compete on price*" (Boost_B, 2017). The conclusions, in combination with a sector assessment – traditional, low tech, comprising an extremely long chain – resulted in a change of direction for which the goal became "*To need only half of the primary raw materials within 10 years with the aid of smart processes and products*" (Boost_B, 2017). The step from this goal to adopting 3D technology can be attributed to the innovation trajectory which Bruil underwent. That is, with the aid of a clear innovation processes – specifically the selected 'FORTH' innovation method – they searched for products, services and/or sectors that were new to them and distinctive to the market. An internal factor that likely aided the organisation to actively address the observed market situation is the highlighted culture, "it is in our culture to challenge ourselves" (News, December 2018).

With respect to the constructed framework, the following conclusions are drawn. The decision to invest in 3D printing technology was influenced by the existence of a price-oriented competition that originated in the economic crisis. In other words, 3D printing fitted the formulated organisational goal and innovative search objective that were created in order to break away from the current industry structure. The identified FORTH method was not seen as a mimetic mechanism since it entails an innovation trajectory (i.e. open exploration of targeted objectives). As such, it did not promote a specific technology. In addition, Bruil's culture probably stimulated the re-evaluation conducted and the decision to act on its findings via innovation. It is therefore viewed as a valuable resource.

5.4.3 De Cromvoirtse

Industry 4.0 in De Cromvoirtse is represented via their people-light order to production chain: "to do this, you must be able to recognise a customer's drawing, convert it into a quotation using software, then automatically have the right materials removed from the warehouse, have it processed, packaged, etc." (Van Ede, 2015). With the aid of smart machines and the connection of different ICT systems, they managed to automate the entire process from quotation request to production.

The first step towards the above process was made in 2008. At that point, however, they did not envision their current reality. Back then, the company noticed an issue with the copying of scales from a drawing and received requests from customers to be available at night for calculations. These two aspects were the stimulus for deciding to build an automatic calculation and quotation system. "*In retrospect, we then built the first link in our people-light order and production chain*" (Van Ede, 2015). The move from this initial step to the automated process the organisation currently possesses was a gradual one. It was one that never had automation in itself as an end goal. The transition was linked to their vision of delivering fast, customized metal. This vision reflects their customers' demands (i.e. delivering very quickly in small series) and is tied to their reflection period back in 2009. "*We developed an important part of our vision during the 2009 recession. We used that quiet time to think about our strengths and weaknesses*" (Van Ede, 2015). The observed transition is, thus, connected to the demands made by their customers, whose relevance was likely reinforced by the recession. The importance of the customers' demands can also be traced to a statement made on the website of the organisation, "metal company De Cromvoirtse is one of the most innovative metal companies in the Netherlands … That has only been possible by listening to our customers and investing in what they need at the right time" (About us, 2019). Customers at that time, can thus been seen as having occupied a position of power. This point can be further interpreted from the quote "*Our customers ask for it [delivering very quickly in small series], to prevent them from getting large intermediate stocks that seize their capital, and which may later turn out to be unsaleable*" (Van Ede, 2015). In addition, the construction of an automatic calculation/quotation system in 2008 is seen as a valuable resource since it functioned as a sort of stepping stone.

5.4.4 GS Metaal

For GS Metaal, the highlighted Industry 4.0 direction is the realisation of a digital factory, which entails a multi-year trajectory. Before turning to the various aspects that make up this trajectory, the motive behind the development of a digital factory and the link with the constructed framework are discussed. An essential point here is the following statement. "Nowadays a metal company can no longer distinguish itself to the customer on the basis of the quality of its cutting, milling, welding and lace work, knows Jan van de Maat [director]. All the more with shorter delivery times and higher delivery reliability" (Link Magazine, 2018). As the original data source did not provide details for this shift, an extra Google query was performed to identify an explanation. This yielded the following insight from an article on the website of ABN-AMRO: "competitive pressure has increased, partly due to the quality improvement of many foreign producers" (Burgering & Kemps, 2016). Foreign players thus seem to have caught up, aligning the dimensions of competition and clarifying the statement made.

Based on a visit to Axoom in 2017, the directors of the company came to the conclusion that the solution to the issue raised above should not be found in machines (e.g. bigger or faster), but in making the internal logistics process more efficient and effective, as well as in the use of data. Consequently, this visit led to the development of a multi-year, digital factory trajectory with as its main goal being "increasing the production capacity in order to serve existing and new customers faster and more reliably" (Link Magazine, 2018). Specifically, they set a target of realising a 30% increase in production capacity by 2019. The article also addressed two secondary goals. Firstly, they wanted to move closer to the customer. Based on the article, there seems to be no clear cause for this other than an indirect effect. It was stated that by enabling their employees to work more effectively and efficiently, they save time which can be spent on customers, to improve product manufacturability. The second additional goal is explained in the following statement, "GS Metaal primarily goes through this complex process for its own customers, …. But the metal company has also taken up the challenge in favour of fellow companies, says Hofmeijer [director]" (Link Magazine, 2018). In collaboration with Axoom and Trumpf, GS Metaal is setting up an experience centre.

Incorporating these outcomes in the constructed framework results in the following conclusions. The decision to build a digital factory was influenced by the observed shift in aspects of quality, as a result of changes in the operation of their international competitors. It initiated a new focus (i.e. shorter delivery times and higher delivery reliability) that needed to be realised. The solution for this focus depicts mimetic behaviour since it adopts an idea or vision presented to them by a consulting firm for digital transformation (Axoom).

Next, more details are given regarding the digital trajectory itself. One aspect is the instalment of software from Axoom. More specifically, the software entails a cloud-based shell that will cover the entire business process and digitally connect all the information of every activity. An essential necessity for the introduction of this software is the presence of lean. As a result, the organisation underwent this step first, as indicated in the article and reflected in the heading of a news bulletin on the firm's website, "LEAN training" (News, November 2018). Implementing the Axoom software not only connects the various internal processes, it also leads to a paperless factory. Again this point is reflected in the article and a news bulletin on the organisation's website, "from now on we can also consult drawings on our tablets at GS Metaal. A great milestone! Piles of paper and printing are now a thing of the past" (News, February 2019).

Apart from an internal focus, GS Metaal aims to increase its capacity by digitally connecting customers and suppliers. An existing example is that communication with a specific supplier recently started to proceed via EDI (electronic data interchange). In addition, the organisation has plans to build a portal to expand the digital communication with external parties. Finally, it is indicated that additional investments will be made at a later stage.

5.4.5 House of Blue Jeans

House of Blue Jeans presents a relatively unique case since it is the only service-oriented firm and, given the absence of connections to a chain, can be considered a micro-business (i.e. fewer than 10 employees). Nevertheless, the store contains a relatively large amount of Industry 4.0 technologies. It accepts payments in DigitByte, and the article further highlights that: 1. "when you place a piece of clothing on the wooden box next to the full-length mirror, 360-degree photos automatically appear on the mirror"; 2. "by moving your finger over the photo, you can virtually rotate the article and view it from all sides. And you immediately get combination suggestions"; 3. "thanks to iBeacons, the system already knows who is in the fitting room, as long as the customer has downloaded the app on his smartphone. There is a screen in the fitting room on which the photos of the item of clothing appear as soon as you hang it on the wall. The screen offers more options, so you can ask the seller to bring a different size and you can already pay for your purchases. If you put a pile of clothing on the counter, the total amount will appear on the counter within two seconds" (National platform_HBJ, n.d.).

The motive for these developments arose from the owner's preferences in combination with connections to an influential external party. The owner was inspired by the fact that technology is evolving so fast, which drove an intention to adopt it in his store. The actual realisation of this inspiration can be traced back to a good friend who told him about Tofugear – a Hong Kong-based digital solutions provider focused on the commerce industry.

Thus, the decision to incorporate Industry 4.0 into the clothing store stemmed from a value held by the owner. The owner is either self-employed or has only a few employees (just a single shop) and thus has full control over any strategic decision. The selected technology built into the store highlights the presence of mimetic behaviour since, again, it copies an idea or vision presented by an influential party (i.e. digital solutions provider Tofugear). The level of influence that this provider possessed is visualised in the following statement. "Before Hauser [owner] knew it, House of Jeans was a demo shop where Tofugear could demonstrate all its gadgets to potential customers and other interested parties" (National platform_HBJ, n.d.).

5.4.6 Itter

In contrast to the other cases, the level of detail regarding the Industry 4.0 transition itself remains rather abstract here. The articles obtained from both the national and regional Dutch platform mostly used the word automatisation. One article included the quote, "*Robots are also the new colleagues at Itter*" (Boost_I, 2018). But the capabilities of these robots remain unaddressed. In addition, the organisation's website only offers the following, general statement, "we are increasingly automating our processes where possible. The administrative processes as well as the production processes" (Automation, n.d.). Nonetheless, their 'people-light production' goal signals the potential presence of smart machines. In addition, a highlighted future vision indicates a possible existence or at least the future intention of an intelligent, connected production process. "*I envision that our customers will control our production process from behind their computer. And I see AGV's (automatic guided vehicles) driving around in a completely people-light factory*" (Boost_I, 2018).

A stated motive is maintaining the production in the Netherlands, since it is mentioned that "*Robots are also the new colleagues at Itter. Because only by automating you are able to produce cheaper and thus keep production in the Netherlands*" (Boost_I, 2018). Additional motives are two internally oriented factors. One is linked to the owners' conscious choice for specialisation, which was made in 2000. It was indicated that "to remain special, the owners embraced Smart Industry" (National platform_I, n.d.). A more specific understanding was found in the other article via the quote, "*Until now, unmanned production lines are mainly focused on large-scale production and not on single-piece production. However, we are already further and can already realise [with their smart factory] a profitable one-piece flow*" (Boost_I, 2018). The second reason can be found in the personality of one of the directors: "*I have been fascinated by new technologies all my life. Not only when it comes to innovations in the metal industry, but actually in every area. We put that preference for progress into practice in our smart factory*", "*I have always been innovative. I always wanted to lead the way*", *and* "*People call me a dreamer. I can fantasize enormously about the future*" (Boost_I, 2018; National platform, n.d.).

Incorporating these outcomes in the constructed framework results in the following conclusions. The decision to build a new Smart Industry factory can be traced to the preference for technological development held by the founder of the organisation. According to the organisation's website, the decision power seems to be located in the owner and, since 2009, his son (the website shows a planner, coordinator and production leader but no other management members; Employees, n.d.). Given that the founder is still involved and that the other decision maker is his son, the founder's values are expected to have influenced the strategic decision regarding Industry 4.0. Additionally, the past decision to be a specialist is considered a valuable resource since it allowed the firm to consider Industry 4.0 in light of its possibilities for facilitating this position. Finally, maintaining production in the Netherlands was stated as a motive. However, its connection to Industry 4.0 is based on indirect signals (i.e.

there is no direct evidence that the robots linked to this statement fit Industry 4.0 technologies). And since switching to robots is not, in itself, a new concept, this motive was left out of the strategic decision-making framework.

5.4.7 Kornelis Caps and Closures

The Industry 4.0 transitions for this organisation are concentrated in their new smart factory where everything will be centred around "*Continuous monitoring, analysis and control of production data*" (Boost_KCC, 2018). It will be a factory that "constantly monitors the condition of the machines, predicts maintenance and generates the big data with which it can produce more efficiently" (Verpakkings management, 2017). To realise such an outcome, the organisation packed their machines with sensors, created an intelligent operating system, and replaced stationary screens with tablets. The level of connectivity realised becomes clear from the following quote, "*The idea that, soon, customers will place an order and the machines will then find the most ideal production sequence themselves...*" (Boost_KCC, 2018). After the realisation of this smart factory, the next project is directed towards their storage since the plan is to build a new automatic warehouse with the inclusion of AGVs. The goal which Kornelis aims to achieve with all of the changes is a fast and error-free manufacturing. "*The future focus at Kornelis is mainly directed towards smart business. Fast and error-free manufacturing of standard and customized products, according to the requirements and specifications supplied by customers. We will be able to make this step in our new smart factory*" (Boost_KCC, 2018).

Regarding the motive behind the aim to manufacture fast and error-free, and build a smart factory, the grant application highlights that "the requirements with regard to hygiene and flawless products have been tightened considerably in recent years. Hygienic production for food related products is an absolute condition. In addition, the market places increasing pressure on error-free production whereby 'zero defect' shifts from a wish to a requirement" (RVO, 2016). What is driving these market shifts, however, remains unaddressed. A potential explanation for the shifted zero defect requirement could stem from the fact that zero defect is part of the Industry 4.0 promotion (see e.g. Ahsmann et al., 2018), and customers are repeating what they hear and/or read. Internal factors that seem to have contributed to the Industry 4.0 transitions at Kornelis are, firstly, their innovating spirit. The grant application mentioned “driven by tightening from the market and the drive to lead the way as an innovator…” (RVO, 2016). Secondly, the move to connect systems and gather data fits with them having completed the automation phase – “*Of course we have already automated everything that can be automated. This enables us to produce huge numbers of caps and closures in a fast and cheap manner. But we are taking a big step further in our new smart factory*” (Boost_ KCC, 2018) – and the possession of high-tech equipment.

With respect to the constructed framework, the following conclusions are drawn. The decision to build a smart factory in which data plays an essential role is influenced by demands from powerful customers. The tightening of the hygiene and zero defect requirements are highlighted in the data source as market factors. Furthermore, the product of Kornelis Caps and Closures is rather standardised – “*You do not need to have studied higher mathematics to make our products. Everyone can do it*” (Boost_KCC_2018) – which increases the potential of the shift in request being a leveraging factor for customers (Porter, 2008). Both points strengthen our choice for considering this result as an external competitive force, specifically as demands from customers who occupy a position of power. The existing presence of automation and high-tech equipment is seen as valuable resources that allowed them to opt for Industry 4.0 technologies to act on the increased demands. Finally, the data included the notion of a spirit of innovation. It is unclear, however, whether this should be considered a value held by decision makers or a valuable resource (i.e. imbedded within the whole organisation). Given the lack of clarity, it was decided to leave this factor out of the framework.

5.4.8 Van Raam Rijwielen

The main reason for this organisation to require adjustments can be found in the growth of the demand for their products. “*Since 2000 we have grown around 20% annually*” (Boost_VRR, 2017). In addition, this growth is expected to continue due to two reasons: “*The aging population remains* [this affects them since Van Raam is a manufacturer of adapted bicycles] *and more people are cycling*” (Province of Gelderland, January 2019). A reason for the latter could be the introduction of e-bikes, which makes cycling in hilly terrains and for long distances more accessible. Consequently, the organisation looked for ways to keep up with the growth. Working 'smart', or Industry 4.0, was likely seen as being able to offer that. The promotion surrounding Industry 4.0 probably contributed to the consideration of this phenomenon since it is so clearly stated that they heard about it; "*Smart Industry, of course we had already heard a lot about it but we did not have a clear picture yet of how to develop it. We then participated in the SI&BM masterclass*" (Smart Industry, January 2017). This statement also highlights that a more specific interpretation of the Industry 4.0 decision stemmed from the Smart Industry and Business Modelling masterclass.

The output of the masterclass was twofold. First, one question raised led Van Raam to consider "*What can go away, what is time-consuming and therefore not working properly and which customers do not want and have to pay for*" (Smart Industry, January 2017). It resulted in a more streamlined intake to production process and the implementation of improvements on the work floor to make work more enjoyable as well as faster and with fewer errors. To realise this, the organisation automated and robotised certain processes. The question remains of to what extent does this reflect Industry 4.0? As with Itter, the capabilities of these robots are not clearly addressed. An aspect that did reflect Industry 4.0 is the organisation's exploration of the use of co-bots and investment in 3D printers. Second, Van Raam developed an e-bike app to establish more contact with their end users. Though the Smart Industry video (January 2017) did not show a link between the app and the masterclass, one was found in an article gathered to confirm the data of the masterclass. "*It was an eye opener for us [masterclass]: we developed a business model in which we will develop services as well as products. We are currently working on an app for reading relevant data from the e-bikes; with that information we can organise the service towards the customer in a smarter – preventive – way*" (Link magazine, 2016).

The masterclass followed played an important role in the direction of Industry 4.0 at Van Raam. The program of the masterclass shows that besides general business modelling advice, attention was placed on technological trends: in the general sense as visible from the inclusion of a trend-watching company, and trend-specific as apparent from the presence of tech consultancy firms specialised in data or the production process (Smart hub academy, n.d.). It thus promoted certain ideas or practices. As a result, the masterclass indicates the existence of mimetic behaviour. Given the particular awareness mentioned of the promotion surrounding Industry 4.0 (i.e. its trendiness), the recognition and assumed necessity of working 'smart' are also considered mimetic behaviour. Lastly, working 'smart' gained its relevance from the need to address the firm's growing product demand, which stemmed from developments in demographics and people's attitude towards cycling. Keeping up with a growing demand is a motive that does not fit the constructed framework. It is therefore included as a separate element.

5.5 Cross-case analysis

For the first framework, the data within each quadrant was analysed and grouped under one or more categories. Quadrant 1 contained two data points. Both addressed a decision maker's (specifically the owner/founder) preference for technological development. Consequently, this category was coded as: *owner's preference for technological development*. Quadrant 2 contained seven data points displaying two distinct directions. One depicted the presence of an *innovative culture*, as derived from statements on the existence of a culture of change. The other grouped the factors: modularisation, specialisation, automatic calculation and quotation system, automated everything, and possession of high-tech equipment. They all represent resources that facilitated the Industry 4.0 decision. In other words, the decision could build upon the existence of these resources and is therefore coded as: *built upon*. Within quadrant 3, two mimetic behaviours are observed. One stems from actions proposed by *influential technology providers*, and are thus also coded as such. The other represents a fashion-driven mimetic behaviour. It emphasizes the effect of concepts that are trending or highly promoted; hence, they fall under the code: *trendiness of Industry 4.0*. Finally, in quadrant 4, factors were found that belonged to two competitive forces. On the one hand, the presence of *powerful customer demands* was identified (coded as such), while the other factors encompassed rivalry aspects. Given the potential destructiveness of the observed forms of competition – competing on the basis of price or on the same dimensions runs the risk of becoming zero sum (Porter, 2008) – these factors were coded as: *destructive rivalry*. This process allowed us to finetune the initial SDM typology (Figure 5.2).

Figure 5.3 displays the fluidity of or relations between the quadrants' content. It shows the combination of quadrants that can be derived from the eight cases. As a result, it allows for a reflection on the dynamics that take place.

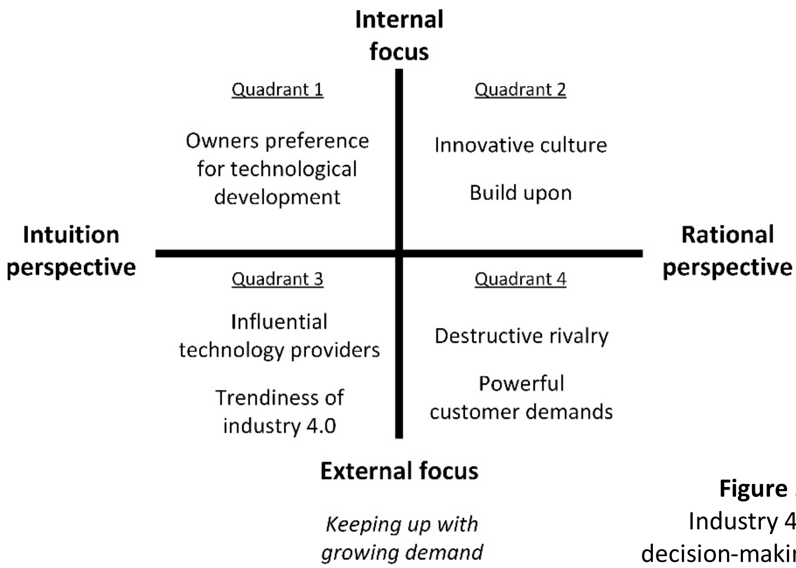


Figure 5.2 Refined Industry 4.0 strategic decision-making typology

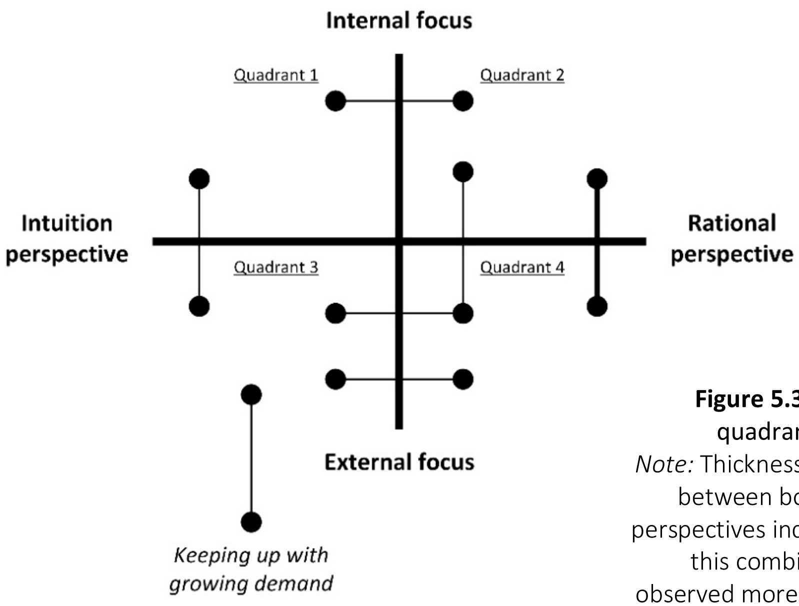


Figure 5.3 Fluidity of quadrant contents
Note: Thickness of the line between both rational perspectives indicates that this combination was observed more than once.

5.6 Reflection

The results from the cross-case analysis show the significance of competition-related motives. However, with respect to customer demands (i.e. "…derived from demands exercised by large customers"; Engelbertink and Woudstra (2017)), our data reveal that it is not necessarily the size of the customers that matters but their level of power, in line with Porter (1979). This broadens the type of customers that require consideration while at the same time, it places a critical note on the conclusion drawn by Freese et al. (2018). These authors found that, in contrast to the traditional view of achieving production benefits or substituting labour, respondents now seem to emphasize the end-user as the primary driver for the deployment of new technology (Freese et al., 2018). Though customer demands are indeed a motive that underlies the decision to opt for Industry 4.0, it is improbable that all demands made by customers will have this effect. The same reasoning goes for the rivalry motive. It is not rivalry in itself, but the form or destructiveness of the competition that triggers the consideration of Industry 4.0. It is notable that, in contrast to a statement made by Müller, Kiel, et al. (2018, p. 247) – "Industry 4.0 aims at overcoming contemporary challenges, such as intensifying global competition…" – our findings focus on the dimensions along which firms compete rather than on the level of intensity. This indicates that we need to consider not only the common rhetoric (i.e. extent of global competition) but also the 'content', as emphasised by Porter (1979).

Figure 5.2 further reveals the existence of motives like the preferences of the founders of an organisation or the effect of the promotional communication surrounding Industry 4.0. The presence of the latter notion, however, does not support the publicity-driven motive highlighted in the introduction. That is, the trendiness of Industry 4.0, or the expected benefits linked to this phenomenon, was not observed on its own; which brings us to Figure 5.3.

Figure 5.3 highlights that, based on the number of observations, there is no particular quadrant that stands out as being the most important influence in the decision-making process regarding Industry 4.0. In addition, it shows that no quadrant functioned on its own. A combination of two or more quadrants was always visible. Combination-wise, it is significant that no direct connections were found between the valuable resources and mimetic behaviour quadrants as well as between the values of decision maker(s) and external competitive forces (i.e. both diagonals). This seems to suggest that the quadrants play two different roles in the process of deciding to opt for Industry 4.0: motives that can be viewed as the *prime movers* – values of decision maker(s), external competitive forces and the additional factor keeping up with growing demand – and motives that seem to represent *necessary facilitators* (valuable resources and mimetic behaviour). The prime movers appear to address the why element of the process, hence they depict the need for a change-related decision, whether in a general sense (e.g. price competition) or already more technology oriented (e.g. fascination for technological development). The necessary facilitators, on the other hand, appear to address the what element; they facilitate the direction. They function as a general stimulus for Industry 4.0 or stimulate specific Industry 4.0 developments. With respect to the former, the trendiness of Industry 4.0 encourages Industry 4.0. Regarding the latter, the influential technology providers directed organisations towards specific Industry 4.0 options, but the build-upon motive also guided firms towards specific developments (e.g. modularization is seen as a pre-requisite for servitization, steering collection of data). The presence of the two distinctive roles would explain why a combination of both diagonals did not occur. It also stresses the fact that an absence of either one of the roles can hinder the adoption of Industry 4.0.

5.7 Discussion

The combination of an observed lag in the adoption of Industry 4.0, the mainly implementation-oriented approach of this issue, and the few and fragmented insights of an alternative perspective led us to our aim of illustrating the complexity and importance of the decision-making phase surrounding Industry 4.0. We addressed this aim by developing an Industry 4.0 strategic decision-making typology framework. The layout of this framework stems from insights from institutional theory and work on strategic management and decision-making. Its content is based on data from eight specific cases, selected from the Dutch national platform and the eastern Dutch regional platform for Industry 4.0.

Besides individual case-related frameworks, a cross-case analysis was conducted that revealed the presence of all four quadrants as well as an external factor (keeping up with growing demand). The results from the cross-case analysis showed that there is more to the decision-making process surrounding Industry 4.0 than current research is revealing so far. In other words, it is not just intensive rivalry or large customer demands that are relevant. The complexity and importance of the decision-making process are further emphasized by the finding that the quadrants play two different roles in the process of deciding to opt for Industry 4.0: prime movers or the why, and necessary facilitators or the what. The presence of both roles seems to be required in order to encourage firms to take the first step towards Industry 4.0 (i.e. the move to the implementation phase). Firms as well as academics should thus not underestimate and neglect the decision-making process with respect to Industry 4.0. This statement, in combination with the importance of the implementation phase that follows, is reinforced in a conclusion made by Machadoa et al. (2019, p. 1117): "companies are jumping into technical matters, which could be necessary to show its possibilities and benefits, but it may be problematic if they forget to do the investigation about what they want to achieve, how the competitive priorities can benefit from digitalisation, and what changes need to be performed".

5.8 Limitations and future research

One restriction stems from the size of the selected cases. Based on staff headcount, all cases – apart from Aebi Schmidt which is part of a larger cooperation, and Bruil which is a questionable case given existing differences in cut-off (e.g. 250 or 500 employees) – can be considered a small to medium-sized firm. In other words, no really large organisations were included in the sample. However, given the limited pool of resources from which small to medium-sized organisations can often draw, the findings and conclusions are deemed most critical for these types of organisations. Second, the selected cases are acknowledged as frontrunners with respect to Industry 4.0. As such, they might have overemphasized the identified innovative culture and owners' preferences for technological development. Nonetheless, these findings show two essential motives with respect to the current observation of a lack of Industry 4.0

adoption as also illustrated, for instance, in a remark found in the paper by Engelbertink and Woudstra (2017, p. 12): “only want to implement the proven technology”. Finally, the study made use of secondary data. Consequently, despite the organisations being presented as ‘smart companies’, actual observations of the Industry 4.0 directions discussed was not possible. To balance this limitation, use was made, where available, of videos depicting the actual situation as well as the adoption of a critical attitude (e.g. in the case of Itter and Van Raam Rijwielen). In addition, we were aware that certain Industry 4.0 options discussed pertained to potential steps to be made in the future. In other words, those ideas had not yet been adopted in practice at the time of the interview. But as long as those ideas fitted with the developments linked to Industry 4.0, this did not pose a problem for our research question. Our interest was focused on the decision-making process behind Industry 4.0, not the implementation process.

With respect to future research, an essential next step to advance scholarly knowledge about Industry 4.0 is to strengthen the justification of the observed quadrant combinations as well as the conditions for their success. It is also recommended to extend the observations within this study towards the implementation phase. In other words, the developed typology is based on the premise that the type of incentives underlying an Industry 4.0 decision will influence the implementation process. The findings presented here lay a groundwork for further research into the extent and manner in which the implementation phase is affected by the decision-making process. The results highlight the influential role being played by technical service providers in the Industry 4.0 decision-making process. This observation gives rise to the question, and subsequently a direction for future research, of what the long-term effects are of the prominent presence of these technical consultancy firms. Are they, for instance, driving organisations towards similar Industry 4.0 constructions? And if so, what would be the impact of that for the competitive position of those organisations?

CHAPTER 6

DISCUSSION

Throughout this dissertation, the main theme has been the phenomenon for which I end up using the label Industry 4.0. A phenomenon that, as visualised earlier (p. 2 and Figure 1.1), has achieved a vast and rapid increase in popularity over the course of my PhD. Consequently, the initial assumption that Industry 4.0 would become noteworthy and require a huge effort by scientists from different disciplines – including HRM scholars – was correct. This makes the research in this dissertation even more relevant today than it was at the start of the project. The four studies presented in this work amount to one conceptual study (Chapter 2) and three studies based on empirical findings (Chapters 3 to 5). Each study contributes to the motive that underlies this dissertation: to build an Industry 4.0 HRM-related knowledge base. A motive that is reflected and concretised in the two research questions that were formulated (1) *what does the Industry 4.0 phenomenon entail* and (2) *in what way does Industry 4.0 affect job design*? At the same time, the findings related to the first research question are relevant to domains beyond HRM.

In this final chapter, I provide answers to both research questions by discussing the overall findings and the theoretical as well as practical contributions for each question separately (6.1 and 6.2). This is followed by a separate section (6.3) where attention is directed towards the future, in order to further expand the Industry 4.0, HRM-related, knowledge base.

6.1 Main research question 1 – the Industry 4.0 phenomenon

6.1.1 Research findings

The third chapter focused on the observed lack of clarity surrounding the meaning of, and diversity in, labels linked to the Industry 4.0 phenomenon. It answered the following raised question *what is the value of Smart Industry*? This question was addressed by developing an understanding of the Dutch Smart Industry label through interviews with Smart Industry experts in the Netherlands. The developed understanding, in turn, enabled us to examine the extent of overlap between the Dutch Smart Industry label and the general term ‘fourth industrial revolution’ as well as existing understandings of Industry 4.0. The first outcome of the study was the creation of two components with which to view Smart Industry: a communicative bubble and a platform for the multiplicity and complexity of current developments. This highlights the promotional intentions, or communication side, of the label on the one hand, and a more nuanced view of the current technological-based developmental streams on the other. Linked to this finding is the depiction of Smart Industry that was constructed (Figure 3.2). The next set of results were related to the conducted comparison. The representation established of Smart Industry was not found to correspond with the term 'fourth industrial revolution' as defined in the online Merriam-Webster dictionary. It, for instance, adopted a too deterministic standpoint towards technology. However, a greater overlap was observed between the Dutch Smart Industry label and the Industry 4.0 label. They were similar in terms of the presence of promotional intentions, an extensive set of predictions, social and IT-related constraints, and the three indicated technological-based developmental streams (connected, informed and equipped). Together, the results strengthened our call to combine forces. That is, it offered evidence that the diversity in labels does not serve an essential purpose for academia. It was therefore concluded that, if those using the Smart Industry label beyond the Netherlands agreed with the representation that was developed in this study, and considering the prevalence and roots of the Industry 4.0 label, we saw no reason for retaining the Smart Industry label within academia. However, given its communicative component, the Smart Industry label was still considered relevant for practice.

The paper presented as the fifth chapter of this dissertation concerns tackling the dominating, implementation-oriented approach that was visible regarding the issue of the lagging adoption of Industry 4.0. This study therefore aimed to *illustrate the complexity and importance of the decision-making phase surrounding Industry 4.0.* To address this aim, we developed an Industry 4.0 strategic decision-making (SDM) typology based on insights from institutional theory as well as work on strategic management and on decision-making. These three bodies of knowledge created the basis, or skeleton, for the typology. In other words, it led to the establishment of an internal versus external focused axis, and a rational versus intuitional perspective axis. Combined, they resulted in four potential motives, or quadrants, underlying the decision to opt for Industry 4.0: values of decision maker(s), valuable resources, mimetic behaviour, and external competitive forces. The empirical assessment of this framework was based on secondary data linked to eight selected cases. More specifically, use was made of interview data obtained from two Dutch, openly accessible, platforms for Industry 4.0 (i.e. their websites, especially the section containing examples of smart companies). For four cases, additional interview data were obtained. Finally, relevant data were also collected from the websites of the selected cases. Besides the individual case analyses, which offered detailed information about the interpretation of the framework for each specific company, a cross-case analysis was conducted. This analysis showed that the decision-making process surrounding Industry 4.0 is driven by motives beyond intense rivalry or demands from large customers; noticeable motives in research and reports thus far. Factors such as influential technology providers, the technology development preferences of owners, or the destructiveness of competition were also found to play a role. Additionally, it was found that the quadrants never acted alone, suggesting that there are two different roles in the Industry 4.0 decision-making process: prime movers (the why) and the necessary facilitators (the what). Both roles appeared to be required in order to reach an Industry 4.0 adoption decision, stressing the reality that the adoption of Industry 4.0 technology could be hindered by the absence of just one of these roles. Overall, we concluded that the decision-making process regarding Industry 4.0 should not be underestimated or neglected by either organisations or academics.

6.1.2 Synthesis

Pulling together the knowledge accumulated during my PhD project related to the first main research question, *what does the Industry 4.0 phenomenon entail*, results in the following answer.

In terms of an understanding of the phenomenon, Industry 4.0 is surrounded by a lack of clarity and unity. For instance, Bosch (2016) found that interviewees mixed-up Smart Industry with new ways of working and lean manufacturing. Members of the Dutch HRM Network also presented different viewpoints. Seeing it as either a future event or as something that already exists "'*It's coming. It's inevitable*'; '*It is already influencing, so it is not like the future, it is already happening*'" (Ten Bulte, 2018, p. 6). In a conversation held on 7th June 2019 with two members of an engineering firm, it was further noted that '*The concept is really just a cloud to the companies. What's in it, I don't think they* *really know*'. Moreover, as shown in the introduction, multiple contributions from academia and practice are also at our disposal, as well as the fact that, to date, no universal definition exists for Industry 4.0. My intention is not to offer such a description here. In other words, I do not claim to have *the* definition of Industry 4.0. Given the extent of depictions already in existence, making that kind of claim would only be adding one more meaning to the vast collection already available. The objective should not be to fight and add to the chaos but to reflect upon it, find relevant common ground and build from there on. That is, effort should go towards addressing and emphasising those similarities that make sense (e.g. though the fourth industrial revolution is a notion which reoccurs across different sources, it was not found to be of value). The developed understanding of Smart Industry (the two components and Figure 3.2) should be considered as such an effort with regard to the phenomenon in the Netherlands. In addition, the conducted comparison with Industry 4.0 is an example of addressing and emphasising significant similarities across labels.

In terms of the realisation of Industry 4.0, the phenomenon is faced with a lagging adoption which was found to have different causes. Part of this problem could be due to the aforementioned unclarity tied to the phenomenon. Not understanding the phenomenon might prevent some organisations taking any action. The slowness in adoption can also be attributed to implementation-oriented barriers. Within the literature, factors related to financial, technical, legal, cultural, and implemental challenges have been found to impede the implementation of Industry 4.0 (Moktadir et al., 2018; Orzes et al., 2018). An example from the study in Chapter 5 (GS Metaal) is '*It makes no sense to implement the Axoom software – and where necessary also Trumpf software and hardware – if our own processes are not made lean and standardised first. … So, before we implement software, we will first make our processes completely lean one by one'* (Appendix D, Link magazine, 2018). In addition to the absence of a clear meaning and the encountered hurdles surrounding the implementation of Industry 4.0, part of the lagging adoption can be ascribed to the decision-making process. Adoption appears to require a combined presence of a prime mover or change motive, such as powerful customer's demands or an owner's (i.e. decision maker's) preference for technological developments, plus an Industry 4.0 facilitator (e.g. valuable resources or technology providers) seem to be required in order to realise the adoption of Industry 4.0.

In sum, it is not possible to formulate a generally accepted understanding of Industry 4.0. Reflections so far highlight that it is a broad, overarching concept encompassing elements linked to technology-based developmental directions that have arisen, the conditions associated with this, as well as a communication bubble. From a practical standpoint this is, unfortunately, not a feasible construction. To be operationally applicable, a concept needs to have one focus (in contrast to the current set of expectations, preconditions, and technological-based developments). A solution would be to discard the broadness and consider Industry 4.0 solely as the technology-based developmental streams. This approach is already visible in some of the studies within this dissertation. The reasonings behind this solution are as follows: it prevents having to work with additional information or designations in order to clarify the intended usage; it ties in to the initial trigger that led to the rise of the label Industry 4.0 (i.e. developments in areas such as communication technology, data storage, and analysis); it depicts concrete developments on an abstract level, rather than the expectations or boundary conditions that flow from it; and its usage seems to be moving in this direction given the shift between the oldest and newest definitions of the Dutch label Smart Industry in Table 1.2. The importance of narrowing the current construction of Industry 4.0 is further emphasised by the fact that certain aspects highlighted in the interviews with the Dutch Smart Industry experts are depicted as individual factors challenging the implementation of Industry 4.0 (Figure 3.1). However, something cannot be part of and at the same time hinder a given concept. The barriers to Industry 4.0 implementation, as well as the importance of the decision-making process, further stress that the phenomenon is far from a rapid (fourth) revolution. In addition, it underscores the level of complexity that surrounds Industry 4.0 – ranging from its meaning to its adoption. Finally, based on the conducted research addressing the decision-making process, it appears that technical service providers are a critical player with respect to this complexity. They seem to be steering, to some extent, the technological directions that are being taken. A finding that was also visible in the conversation held on 7th June 2019 with two members of an engineering firm: '*They [organisations] really want to be helped.*

That you actually advise them, with which they can and cannot gain something'. The importance of technical service providers in the Industry 4.0 context can also be derived from the large increase in the number of IT service providers in the Netherlands since 2014 (Figure 6.1).

Figure 6.1 Development of number of IT consultancy firms in the Netherlands
Source: StratisticsNetherlands-CBS (2019)
Notes: After 2014, the year when Industry 4.0 was introduced in the Netherlands, a steep growth in the number of IT consultancy firms is visible. The graph is based on data from the first quarter of each year. The data up to and including 2017 are final, the data for 2018 are further provisional and the data for 2019 are provisional.

6.1.3 Contributions to science and to business practice

With the phenomenon now being so prevalent in academia as well as in practice, the contributions of the results answering the first main question in this dissertation are often equally applicable to both areas. The finding that there is coherency within the apparent chaos – that it is possible to state that factors associated with Industry 4.0 encompass elements linked to: the technology-based developmental directions, associated conditions, and a communication bubble – for instance aids both domains by enhancing their comprehension of Industry 4.0. This contribution is further enhanced by the proposed solution offered in the above synthesis. That is, a certain degree of agreement is visible when adopting a broad perspective, and this offers a preliminary level of clarity that can be utilised. The proposed solution will provide a more focused meaning of Industry 4.0 that can be adopted within research and used by organisations. It shifts the concept from an unworkable set of factors to one that emphasises the beauty of a technical bundle. Without downplaying the individual technical aspects (e.g. big data analytics, augmented reality, IoTs), it highlights and inspires the possibility of adopting a combined perspective – connected, informed and equipped. This offers a workable content to those scholars interested in conducting research into this bundle. Considering only the three technical-developmental streams, further stresses the effort that is still required to unravel what is being achieved with them. Although certain examples have been provided (see Subsection 1.1.2), these do not present an exhaustive list as much experimentation is still taking place (e.g. within the currently 43 Fieldlabs in the Netherlands). It also helps eliminate the notion that Industry 4.0 is only relevant for a select group of organisations. Hermann et al. (2016) stated that Industry 4.0 can be considered a subset of the Industrial Internet label since the latter has a broader focus, while Industry 4.0 is seen as being solely focused on manufacturing and logistic processes. The current technological developments are widespread and should not be constrained just because the communication bubble has framed them as such. Additionally, the proposed solution helps tackle the earlier raised issue in the conversation with the members of the engineering firm: '*The concept is really just a cloud to the companies. What's in it, I don't think they really know*'.

The findings also open up a dialogue, especially for scholars, concerning the attainment of a unified label for the phenomenon. The use of a single label, which can only be established by discussing the topic, prevents the need to add duplicate key words and facilitates the gaining of insights into what is published on the phenomenon. It is also expected to encourage cross-country, and especially cross-continent, collaborations because the use of one label provides greater awareness of other scholars conducting research in this domain. In addition, it will help eliminate the idea that subsets are needed. Given that national platforms have already invested heavily in their current labels, the feasibility of an agreement on a single label for use in practice is questionable. This fact does not automatically mean that conducting such a discussion is completely irrelevant for practice. More cross-country interactions are also thought to be beneficial here by improving the ability to learn from each other's approaches.

Thirdly, the results highlight the richness of the existing literature – a fact that sometimes seemed to have been overlooked. In other words, it was observed that Industry 4.0 was mostly considered from a very technical deterministic point of view. However, in the literature, such an approach has long been viewed out as an "incomplete account of technology and its interaction with organisations" (Orlikowski, 1992, p. 400) and alternatives have been offered. Moreover, the necessity for Industry 4.0 is often framed in relation to the rapidly growing international competition or large customer demands (e.g. Huizinga et al., 2014; Müller, Kiel, et al., 2018). Although this is not necessarily incorrect, it does adopt a rather basic argumentation. One that is expandable with existing bodies of knowledge – for example the work of Porter (1979) or the decision-making literature. Chapters 3 and 5 thus drew attention to the value of, but on occasion overlooked literature that is available to us. Especially when addressing concepts that display characteristics of a management hype, as appears to be the case with Industry 4.0 (e.g. Madsen, 2019), it is essential for scholars not to fall prey to such framing. Academics should use their knowledge to expose hyped concepts and either discard or make more solid institutions out of them.

Finally, Chapter 5 offers organisations a set of practical insights from frontrunners with respect to the motives behind their Industry 4.0 adoption decisions (e.g. destructive competition or technical preferences), the decisions or changes made or planned (e.g. 3D concrete printing; people-light smart, connected process from order to production or customer data collection) and a brief mention of concerns that should be taken into consideration when implementing such decisions (e.g. financial issues, acceptance and skills of employees, or ethical and legal aspects).

6.2 Main research question 2 – Industry 4.0 and job design

6.2.1 Research findings

The second chapter was concerned with tackling the lack of HRM-related research into Industry 4.0. Accordingly, the aim of this study was to *encourage and guide Smart Industry HRM-related research.* This aim was addressed by presenting upcoming challenges developed using a job design lens. To strengthen our call for more HRM-related research into Industry 4.0, the massive employment debate, present at that time, was first discussed. Both sides of the debate were examined as well as the position that we took within this debate – we sided with the view that the technological developments would not result in a jobless future and, as such, the field of HRM remained an essential area of research with respect to Industry 4.0. Next, to show the importance of raising HRM-related questions in relation to the phenomenon, and to offer examples, indications of issues arising from Industry 4.0 were provided using a job design lens. In other words, our understanding of the phenomenon was combined with a self-constructed overview of research on job design in order to highlight challenges and raise scholars attention towards HRM in an Industry 4.0 context. Besides conceptual challenges, we explored the direct effects of Industry 4.0 on job characteristics and examined its moderating impacts. We, for instance, noted that the manner in which core job characteristics continued to exist was subject to change, that their relevance should not be considered self-evident, that new characteristics might emerge and, the strength of observed relationships between a job characteristic and its outcomes might change. Additionally, we indicated that the prominence of connectivity or networks surrounding Industry 4.0 emphasised the consideration of a configurational approach. Taken together, it was concluded that the highlighted challenges were not meant as an exhaustive list of the impact of Industry 4.0, but they did show the importance of conducting research towards the phenomenon from a more social, or HRM, perspective.

Encouraged by the observation that the social dimensions "deserve greater attention from scholars than they have received heretofore" (Oldham & Hackman, 2010, p. 468), the fourth chapter focused on an essential but unexplored job characteristic with respect to Industry 4.0. Here, the formulated research question was: *what developments can be observed with respect to the social context of work as a result of the Industry 4.0 work context*? To answer this question, semi-structured interviews were conducted within two technical service providers and two production organisations. Results highlighted the following developments regarding the social context of work due to Industry 4.0. First, the presence of a digital way of interacting was observed, but this was seen as related more to existing tools (e.g. email) than to Industry 4.0 transitions. On the other hand, the data also emphasised the value that was attached to face-to-face communication. It further showed that both means, digital and social, appeared to have different purposes (e.g. offer quick solution/minimise interruption versus allow discussion/prevent alienation). This distinction was expected to persist in an Industry 4.0 context. Secondly, the findings revealed two ways in which Industry 4.0 influenced the social context of work. It led to changes in the intensity and/or source of existing social characteristics (e.g. introducing 3D printers increased the extent of social support between certain employees and changed the source of dependency) and also introduced new structures or emphasised known ones (lending vs. teams).

6.2.2 Synthesis

Over the past years, the set of job design characteristics has developed over time (Appendix F). The advancement of these characteristics, and their influence on the design of jobs, is not expected to stand still. Opportunities such as Industry 4.0 ensure the continued evolvement of this topic. The issue is, however, what the new developments will be. Combining the understanding of Industry 4.0 discussed above with the accumulated knowledge on job design leads to the following answer to the second main research question: *in what way does Industry 4.0 affect job design*?

First, one of the most discussed effects of Industry 4.0 concerns the knowledge characteristic *skill variety* (definitions can be found in Appendix A). The main perception is that skill variety will increase. A given reason, in the study conducted by Bosch (2016), is the influence of customer involvement. This fits with the identified increase in customer contact by the engineers at the technical service providers. It implies that they will need to possess social skills alongside their technical expertise. The literature further adds to the perception through the presented summaries of diverse competences that become important for certain employees, like managers or technicians (Corporaal et al., 2015; Grzybowska & Łupicka, 2017). Contrary to these indications, there are also signs that depict a narrowing in skill variety. An example arises from the possibility to design jobs such that they operate on the basis of following digital, visual work instructions (e.g. using augmented reality). This could imply a need for only a limited set of skills. *Specialisation* is another knowledge characteristic and is closely linked to skill variety. The following quote from Chapter 4, connected to the observed lending structure, indicates a change in this characteristic. '*In the past, you sometimes delved into a field of knowledge in order to gain some experience, to understand, or become better at it. Nowadays that does not work anymore*'. This highlights a shift from the ability to widen one's field of expertise, when necessary, to the need to opt for specialisation. Turning to the 'task' category, a challenge was detected related to the *task identity* characteristic. Bosch (2016, p. 39) noted that "most participating companies agree on the fact that Smart Industry does not lead to a situation in which employees can perform whole tasks alone or complete an entire product by themselves. In fact, it might even be the other way around as products become more complex and contain multiple specialist areas". Producing an end product by oneself or, alternatively, applying job rotation as a way to realise task identity no longer seems to be applicable in every case. In other words, the importance of this characteristic remains but achieving task identity could require a new approach. The finding of a transition to self-steering, multidisciplinary teams within the technical service providers confirmed the challenge and suggests an alternative approach to solve the problem. Grouping different specialism together will likely give the individual employees an impression of the whole; as is also the end goal of job rotation. Another task characteristic that was affected is *feedback from the job*. The enhanced data collection and communication means linked to Industry 4.0 (e.g. sensors, tablets, and (smart)machines in a networked setting) opens the possibilities to instantly receive real-time feedback. Feedback from the job therefore has the potential to become more data-driven: "there is no doubt among respondents on the fact that Smart Industry leads to more factual feedback on the job" (Bosch, 2016, p. 42). Given the close association between this characteristic and *feedback from others*, the latter characteristic would, inherently, also be affected, for instance by focusing more on personal feedback. A statement from a respondent in study 3 (Chapter 4) substantiates this: '*With the what, data often does not lie. But you also have a how. How do people do that? How are people doing? Then you come more towards the soft side. Passion is sometimes very difficult to make smart*'. Further, a quote reported elsewhere from one

HRM expert showed that expectations exist regarding the use of data beyond factual performance: "*'Because you have big data, you have much more qualified information about performance of people but also about the social network of people'*" (Ten Bulte, 2018, p. 8). Interviewed members of the Dutch HRM Network also addressed the impact of a more data-driven feedback approach. That is, Krüger (2018) mentioned that some of the experts predicted a more distant relationship between line managers and employees due to the possibility of supervising through data. Other experts, on the other hand, suggested a shift towards a more equal relationship as a result of self-managing teams (Krüger, 2018). This is supported by our findings within the technical service providers, presented in Chapter 4: '*I would not know who I should see as my boss…*'. Irrespective of how feedback will be arranged in an Industry 4.0 context, there is consensus that face-to-face communication will not disappear. Both the HRM experts and the findings within Chapter 4 emphasise the importance and value of personal contact (Habraken et al., 2019; Krüger, 2018). A result that applies to more social characteristics like social support. Staying within the social category, developments were observed concerning *interactions outside the organisation*. Engineers' contact with customers has increased, their types of customers expanded, and the presence of a lending structure was found. Consequently, this not only signals a change in the relevance of this characteristic, but also its content. Adding conculega's and other programmers to the traditional set of suppliers and the 'regular' customers of engineers. These developments were, however, not found for the two production cases in Chapter 4. Besides the interactions with customers, Industry 4.0 expectations also depict changes related to suppliers. Here the prediction is that Industry 4.0 will result in far-reaching supply chain cooperation. An example highlighting a step towards the realisation of this prediction is presented in the following quote from study 3 (Chapter 4): '*Bosch has obliged their suppliers to place barcodes everywhere so that everything is registered. The entire tracking and tracing process has been optimised in that organisation. Their suppliers must cooperate in this. As a result, you see that cooperation is becoming more and more intensive*'. The question, however, remains as to what extent and in what way will such developments affect the social interactions between a firm and its suppliers. A notable effect regarding *task interdependence* was a visible shift in the source of interdependence; from an external to an internal party. For instance, the introduction of a 3D printer replaced an external supplier in Asia with employees within the organisation.

In terms of characteristics without a certain status (i.e. only occurring in three or less job design models), the following conclusions can be drawn. Besides the more common task interdependence, Morgeson and Humphrey (2008) included *two other forms of interdependence*. One that broadens the task interdependence from the individual- to the team-level, and another that focuses on outcome or goal interdependence rather than task. This publication by Morgeson and Humphrey (2008) appears to be the only paper that added these characteristics to a job design model. Nevertheless, the introduction of self-steering multidisciplinary teams emphasises the importance of goal and outcome interdependence (the extent to which an individual's goals overlap with, or feedback and rewards are linked to, another person; Morgeson & Humphrey, 2008). Based on the observed struggle with forming multidisciplinary teams – a separate team of software engineers was created that delivers knowledge to all other teams – it would seem that the same applies to the interdependence between teams characteristic. In addition, Parker et al. (2001, p. 423) included the characteristic *emotional labour or demands*: "a requirement for individuals to manage their emotional expression in return for a wage". Results from our studies show that there are indications that, in an Industry 4.0 context, more employees will be required to interact with customers and that a switch to offering services instead of purely selling products is being made (e.g. as with Aebi Smidt in Chapter 5). Both these findings support the importance of emotional demands. The question then arises whether this should be a separate job design characteristic as in the model by Parker et al. (2001). The essence of this characteristic, the ability to control one's emotions, could also be covered by the broader skill variety characteristic.

To summarise, the characteristics that are visible in most of the job design models (e.g. feedback from job and others, skill variety, interaction outside the organisation) are expected to remain relevant. It is more the content of these characteristics that are susceptible to change (e.g. more data-driven feedback, a shift in the source of task interdependence, a new task identity approach). However, conclusions go beyond the imbedded characteristics. Specifically, it was found that the underexposed dimensions of interdependence deserve greater recognition. Further, the emotional demands characteristic, although content-wise essential within an Industry 4.0 context, does not need to be included as a separate characteristic.

6.2.3 Reflection

Section 6.1 commented on the complexity that surrounds Industry 4.0, and the intention of several studies within this dissertation to address that complexity. However, despite the presented reflection, proposed solution, and the relevance of the decision-making process, Industry 4.0 remains a phenomenon that is still unfolding. That is, progress has been made with respect to understanding and realising Industry 4.0, but an end point has not yet been reached. There is still more to learn about all that the three technical-developmental streams can offer us (to decipher its possibilities), and steps to take in the adoption of those opportunities. Consequently, the presented synthesis should be considered as a provisional answer to the question *in what way does Industry 4.0 affect job design*? That is, as an answer based on the knowledge that is presently available to us. In addition, the developments presented should not be viewed as a general answer to the question raised since the context of an organisation influences the end result. Findings observed within the context of a technical service provider are, for instance, not necessarily applicable to a more production-oriented company. Outcomes are further dependent on how people within an organisation act on a decision made as illustrated with the following quote: "*'It allows you to perform quicker feedback loops and big data can give you a lot of insight in performance. But it highly depends on what you do with the data otherwise it is useless. Management style is very important'*" (Bosch, 2016, p. 34). Finally, given the design of the studies conducted for this PhD project, characteristics other than those addressed within this research might also be affected. One example, raised in the introduction but not addressed in this dissertation, is the expectation of a shift from physical demanding occupations to sedentary occupations (Parker & Zhang, 2016).

6.2.4 Contributions to science and to business practice

Madsen (2019, p. 84) comments that "while some studies suggest that I4.0 could, for example, have positive effects on certain industrial performance metrics or the performance of SMEs, so far there is relatively little systematic research on the actual effects and merits of I4.0 and what actual impact the concept has had on organizations and industries in different parts of the world". This quote highlights that insights into the effects and merits of Industry 4.0 are scarce and the findings related to this dissertation's second research question offer an initial contribution to filling this gap in knowledge on the actual impact of the concept. It provides awareness, to both the scholarly and practical fields, of the job design developments currently visible.

For scholars, the findings further highlight the need to re-evaluate the adopted perspective or approach often taken with regard to job design characteristics. That is, attention should move beyond the more embedded characteristics, and focus more on appreciating the value that underexposed characteristics can hold (as was the case with the interdependence dimensions). Further, academic research could work towards building clearer argumentation as to why a newly proposed characteristic (e.g. emotional demands) might not hold value. In line with these statements, a suggestion for the job design field would be to create a tradition of discussing, maybe every three years, the relevance and content of characteristics that have recently been proposed as well as those that have been around for some time. The perceived benefit of such a discussion not only stems from the concern that certain characteristics are underexposed (whether fairly or not) but also because the concept of job characteristics is not in itself well-grounded. In other words, there is no clear definition of what a job characteristic entails. Providing such a definition is perhaps impossible given that job characteristics are positioned in a context that changes over time. Consequently, a discussion space could be a feasible alternative. In addition, it could offer solutions to a number of other issues including the presence of existing characteristics without a solid status and the current ability to introduce any new characteristic (see Appendix F). Further, such discussions could provide a fresh look at those characteristics that are ingrained but just as susceptible to a changing context.

With respect to practitioners, the results raise several points that organisations could consider. For instance, when considering a shift towards broadening job descriptions (e.g. adding customer consultation to the job of an engineer) and/or the work context (e.g. collaboration between colleagues with diverse backgrounds in multidisciplinary teams), the range of skills required will increase. Consequently, employees will need to possess additional skills such as the ability to control emotions or communicate with people from different backgrounds. However, increased skill variety is not a given outcome of Industry 4.0. That is, Industry 4.0 also allows for the creation of important but narrow jobs. An example is a picking and assembly task based on immediate, digital, visual guidance. Such constructions may offer meaningful opportunities for people with a distance to the labour market. This is a direction that Dutch organisations should not overlook given the participation act introduced in the Netherlands in 2013. This agreement states that, together, the government and the market will create an additional 125,000 jobs by 2026 for people with a distance to the labour market. In addition, the results regarding the feedback characteristics show that the usage of data for feedback requires some balancing. For factual content (e.g. whether the speed of production is in line with an established day target), there appears to be some agreement and a visible transition towards employing real-time data. However, when extending the use of data towards more personal content the feasibility becomes more questionable, both technically and from an ethical perspective. In such situations, it is therefore advisable to know clearly what is achievable, why such a step is necessary, and to involve the relevant employees. Further, it should not be forgotten that personal contact, whether for feedback or other purposes, cannot be eliminated completely. This is not just for technical reasons, our results highlighted that face-to-face and digital means of interaction appear to possess distinct values (i.e. discussion versus efficiency). Values that should both be considered and used to their advantage. As an example, one should consider, for a given skill, whether it is better to train by means of personal contact or through a digital means such as augmented reality.

6.3 Future directions

6.3.1 Research suggestions

The first suggestion stems from the fact that effort is still required with regard to unravelling what is being achieved with Industry 4.0. A few examples were presented in the introduction of this dissertation, but by no means does this amount to an exhaustive list of the manner in which Industry 4.0 is shaped within practice. Opportunities exist, therefore, in extending our understanding of the outcomes realised from the three technical-developmental streams. This is especially true when using a broad lens, for instance by adopting a global perspective and/or including various industry types. Exploring this research direction becomes of further interest if the focus is not only directed towards the manner in which Industry 4.0 is shaped within organisations but also incorporates the knowledge or findings gained in, for instance, Fieldlabs as well as what technical service providers are offering firms with respect to Industry 4.0. Also an assessment of the extent to which their offerings are reflected in practice would be valuable.

This latter statement is linked to the second suggestion: the exploration of the level of mimetic behaviour taking place around Industry 4.0. Are organisations, in a specific sector, heading towards adopting similar organisational approaches? A quote from the firm GS Metaal in Chapter 5 gives the impression that this might be a reality: "together with Trumpf and Axoom we are going to set up an experience center here, where other metal companies in this region can go to get a sense of what a smart factory for metalworking entails and what steps they should take to that end" (Appendix D, Link magazine, 2018). An investigation of this research question is of particular interest given the framing of Industry 4.0 as remaining competitive. Consider, for instance, the remark made by a Dutch Smart Industry expert in Chapter 3: '*Anyway this is the objective, accelerating technological innovation and digitalisation of the industry and increasing competitiveness of the Dutch industry which is crucial for future prosperity and welfare in the Netherlands'*. Yet, when mimetic behaviour is taking place to a large extent, the very thing that is now promised as helping companies improve their competitive advantage will, over time, become the industry standard.

Thirdly, Chapter 5 highlighted the relevance of a decision-making lens towards the adoption of Industry 4.0. A future research suggestion would be to extend the research on this 'adoption' topic by combining the existing implementation focus with the added decision-making perspective. Such a combined approach would provide a more holistic view on the realisation of the phenomenon. A potential research direction might be to assess to what extent, and in what way, the implementation phase of Industry 4.0 is influenced by the type of Industry 4.0 decision-making typology.

Besides the phenomenon itself, this dissertation has looked at the way in which Industry 4.0 has affected job design. Since Industry 4.0 is still unfolding, the findings discussed in these conclusions can only offer a provisional answer to the respective, raised research question. An answer based on available knowledge to date. Consequently, a suggestion for future research is to continue the inquiry into the way in which job design evolves as Industry 4.0 unfolds further.

A final suggestion is to address, in general, the issue of the scarce set of insights into the actual effects and merits of Industry 4.0, as noted by Madsen (2019). A potential research direction is to consider the effects for HR practices. But also broader, less HR-related topics, such as organisational performance (as visible in the comment by Madsen (2019)), sustainability, and the impact on contemporary demographic challenges are worth exploring. Especially since these latter concepts have already been emphasised in earlier reports regarding Industry 4.0: "Industrie 4.0 will address and solve some of the challenges facing the world today such as resource and energy efficiency, urban production and demographic change" (Kagermann et al., 2013, p. 5) *and* "Smart Industry can contribute to [solving] the problems our society faces with regard to ageing" … "Smart Industry can also contribute to more efficient agriculture (e.g. precision farming), enhanced food security through the network-centric and information approach" (Huizinga et al., 2014, p. 39).

6.3.2 New beginnings

To stimulate new PhD projects into Industry 4.0, and hence to inspire new beginnings, I suggest three potential PhD themes with associated research questions.

- PhD project 1. Shaping Industry 4.0

  Focused on the expression of Industry 4.0 in practice
  - What are similarities and differences in the shaping of Industry 4.0 within various industries?
  - To what extent does the shape of Industry 4.0 differ across countries? And in what way do institutions and national cultures determine these differences?
  - To what extent are findings from experimental settings, such as Fieldlabs, transferred to practice? And which factors are responsible for the success of such transfers?
- PhD project 2. Addressing grand topics

  Focused on an assessment of the 'promised' merits of Industry 4.0 in terms of major outcomes
  - To what extent is Industry 4.0 contributing to internal and external sustainability?
  - Which demographic challenges, for instance an aging population or migration, are being tackled through Industry 4.0?
  - To what extent and in what way is Industry 4.0 enhancing organisational performance?
- PhD project 3. Job design, extended

  Focused on additional job design perspectives
  - In what way are employees crafting their jobs within the paradigm of Industry 4.0? And what outcomes do employees (aim to) derive from these activities?
  - What is the role of job design in achieving a successful introduction of Industry 4.0? What types of job design will foster a smooth and successful introduction of Industry 4.0?
  - To what extent does Industry 4.0 stimulate a broader consideration of job design goals (e.g. not just as a means for boosting motivation or well-being but also as a vehicle for individual learning and development)?

References

Ahsmann, B., van den Akker, E., van Baars, G., Baartmans, R., Blankendaal, J., Bossert, R., . . . Thuis, B. (2018). *Smart Industry roadmap: Onderzoeksagenda voor HTSM en ICT en routekaart voor de NWA*. Retrieved from https://wetenschapsagenda.nl/gecombineerde-htsmictnwa-onderzoeksagenda-smart-industry/

Babbage, C. (1835). *On the economy of machinery and manufacturers*. London, UK: Charles Knight.

Bainbridge, S. (2015). In the future, what will people do? In T. Dolphin (Eds.), *Technology, globalisation and the future of work in Europe: Essays on employment in a digitised economy* (pp. 80-85). London, UK: Institute for Public Policy Research (IPPR).

Barney, J.B. (1991). Firm resources and sustained competitive advantage. *Journal of Management, 17*(1), 99-120. doi: 10.1177/014920639101700108

Barney, J.B. (1995). Looking inside for competitive advantage. *Academy of Management Perspectives, 9*(4), 49-61. doi: 10.5465/ame.1995.9512032192

Bechtold, J., Lauenstein, C., Kern, A., & Bernhofer, L. (2014). *Industry 4.0 – The Capgemini Consulting view: Sharpening the picture beyond the hype*. Retrieved from https://www.de.capgemini-consulting.com/resources/industry-40-capgemini-consulting

Berentsen, W., Buiting, K., Huizinga, G., Kolk, T., Smit, R., Bouws, T., . . . Grosfeld, T. (2014). *Actie agenda Smart Industry: Dutch industry fit for the future*. Retrieved from http://www.kennisbanksocialeinnovatie.nl/nl/kennis/kennisbank/smart-industry--dutch-industry-fit-for-the-future/1287?q

Berger, T., & Frey, C.B. (2015). Bridging the skills gap. In T. Dolphin (Eds.), *Technology, globalisation and the future of work in Europe: Essays on employment in a digitised economy* (pp. 75-79). London, UK: Institute for Public Policy Research (IPPR).

Bernstein, A., & Raman, A. (2015). The great decoupling. *Harvard Business Review, 93*(6), 66-74.

Beyer, J.M. (1981). Ideologies, values and decision making in organisations. In P.C. Nystrom & W.H. Starbuck (Eds.), *Handbook of Organisational Design* (pp. 166-202). Oxford, UK: Oxford University Press.

Birtch, T.A., Chiang, F.F.T., & Van Esch, E. (2016). A social exchange theory framework for understanding the job characteristics – job outcomes relationship: The mediating role of psychological contract fulfillment.

The International Journal of Human Resource Management, 27(11), 1217-1236. doi: 10.1080/09585192.2015.1069752

Blanchet, M., Rinn, T., Von Thaden, G., & De Thieulloy, G. (2014). *Industry 4.0: The new industrial revolution - how Europe will succeed*. Retrieved from https://www.rolandberger.com/en/Publications/pub_industry_4_0_the_new_industrial_revolution.html

Bosch, D. (2016). *Job characteristics in smart industries and the challenges for job design.* (Master degree, University of Twente, the Netherlands). Retrieved from University of Twente theses database, http://purl.utwente.nl/essays/71526

Bouma, T., Bakker-Tauritz, B., Balcha, E., Van Dijck, S., De Ruiter, A., Schepers, H., & Freese, C. (2018). Arbeidsmarkt en toekomst van werk. In J.M. Van Sonsbeej, R. Dekker, A. Van der Giezen, K. Hermans, M. Schols, & C. Vooren (Eds.), *Kennisageda SZW 2019-2022* (pp. 13-21): Ministry of Social Affairs and Employment.

Brynjolfsson, E., & McAfee, A. (2014). *The second machine age: Work, progress and prosperity in a time of brilliant technologies*. New York, NY: W.W. Norton & Company.

Butler, A.B., Grzywacz, J.G., Bass, B.L., & Linney, K.D. (2005). Extending the demands-control model: A daily diary study of job characteristics, work-family conflict and work-family facilitation. *Journal of Occupational and Organizational Psychology, 78*(2), 155-169. doi: 10.1348/096317905X40097

Chiaburu, D.S., & Harrison, D.A. (2008). Do peers make the place? Conceptual synthesis and meta-analysis of coworker effects on perceptions, attitudes, OCBs, and performance. *Journal of Applied Psychology, 93*(5), 1082-1103. doi: 10.1037/0021-9010.93.5.1082

Christian, M.S., Garza, A.S., & Slaughter, J.E. (2011). Work engagement: A quantitative review and test of its relations with task and contextual performance. *Personnel Psychology, 64*(1), 89-136. doi: 10.1111/j.1744-6570.2010.01203.x

Corporaal, S., Alons, M., & Vos, M. (2015). *Working paper: Werken in de nieuwe industriële realiteit - een verkennend onderzoek naar de verwachtingen van werkgevers over jonge technici*. Retrieved from http://files.m14.mailplus.nl/user314100244/22853/Werken%20in%20de%20nieuwe%20industri%C3%83%C2%ABle%20realiteit.pdf

Davenport, T.H., & Kirby, J. (2015). Beyond automation. *Harvard Business Review, 93*(6), 58-65.

Davies, R. (2015). *Industry 4.0. Digitalisation for productivity and growth*. Retrieved from http://www.europarl.europa.eu/thinktank/en/document.html?reference =EPRS_BRI(2015)568337

Delery, J.E., & Doty, D.H. (1996). Modes of theorizing in strategic human resource management: Tests of universalistic, contingency, and configurational performance predictions. *Academy of Management Journal, 39*(4), 802-835. doi: 10.5465/256713

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining gamification. In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning future media environments* (pp 9-15). doi: 10.1145/2181037.2181040

DiMaggio, P.J., & Powell, W.W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review, 48*(2), 147-160. doi: 10.2307/2095101

Drath, R., & Horch, A. (2014). Industrie 4.0: Hit or hype? *IEEE Industrial Electronics Magazine, 8*(2), 56-58. doi: 10.1109/MIE.2014.2312079

DutchSmartIndustryTeam. (2015). *Vernieuwing door samenwerking in Smart Industry: Jaaroverzicht 2015*. Retrieved from https://smartindustry.nl/wp-content/uploads/2019/04/Jaaroverzicht-2015-vernieuwing-door-samenwerking-in-Smart-Industry.pdf

Engelbertink, D., & Woudstra, S. (2017). *Managing the influences and risks of Industry 4.0.* (Bachelor degree, University of Twente, the Netherlands). Retrieved from University of Twente theses database, http://purl.utwente.nl/essays/72705

EuropeanCommision. (2017, November 2018). Coordination of European, national & regional initiatives. Retrieved from https://ec.europa.eu/digital-single-market/en/coordination-european-national-regional-initiatives

Finkelstein, J., & Newman, D. (1984). The third industrial revolution: A special challenge to managers. *Organizational Dynamics, 13*(1), 53-65. doi: 10.1016/0090-2616(84)90031-7

Flick, U. (2018). Doing qualitative data collection – charting the routes. In U. Flick (Eds.), *The SAGE Handbook of Qualitative Data Collection* (pp. 3-16). London, UK: Sage. doi: 10.4135/9781526416070.n1

FME. (2015). *Aan de slag met Smart Industry.* Retrieved from https://www.fme.nl/nl/whitepaper-slag-smart-industry

Ford, M. (2015). *Rise of the robots: Technology and the threat of a jobless future*. New York, NY: Basic Books.

Freese, C., Dekker, R., Kool, L., Dekker, F., & Van Est, R. (2018). *Robotisering en automatisering op de werkvloer: Bedrijfskeuzes bij technologische innovaties*. Retrieved from https://www.rathenau.nl/nl/digitale-samenleving/robotisering-en-automatisering-op-de-werkvloer

Frey, C.B., & Osborne, M.A. (2013). *The future of employment: How susceptible are jobs to computerization?.* Oxford, UK: Oxford Martin Programme on Technology and Employment.

Fried, Y., & Ferris, G.R. (1987). The validity of the job characteristics model: A review and meta-analysis. *Personnel Psychology, 40*(2), 287-322. doi: 10.1111/j.1744-6570.1987.tb00605.x

Gašová, M., Gašo, M., & Štefánik, A. (2017). Advanced industrial tools of ergonomics based on Industry 4.0 concept. *Procedia Engineering, 192*, 219-224. doi: 10.1016/j.proeng.2017.06.038

Gerring, J. (1999). What makes a concept good? A criterial framework for understanding concept formation in the social sciences. *Polity, 31*(3), 357-393. doi: 10.2307/3235246

Gig economy. (n.d.). In *Cambridge Advanced Learner's Dictionary & Thesaurus Online.* Retrieved from http://dictionary.cambridge.org/dictionary/english/gig-economy

Goertz, G. (2006). *Social science concepts: A user's guide*. Princeton, NJ: Princeton University Press.

Grant, A.M. (2008). The significance of task significance: Job performance effects, relational mechanisms, and boundary conditions. *Journal of Applied Psychology, 93*(1), 108-124. doi: 10.1037/0021-9010.93.1.108

Grant, A.M., Fried, Y., & Juillerat, T. (2011). Work matters: Job design in classic and contemporary perspectives. In Z.S. (Eds.), *Handbook of Industrial and Organizational Psychology* (Vol. 1, pp. 417-453). Washington, DC, US: American Psychological Association. doi: 10.1037/12169-013

Grant, A.M., & Parker, S.K. (2009). 7 Redesigning work design theories: The rise of relational and proactive perspectives. *Academy of Management Annals, 3*(1), 317-375. doi: 10.1080/19416520903047327

Grzybowska, K., & Łupicka, A. (2017). Key competencies for Industry 4.0. *Economics & Management Innovations, 1*(1), 250-253. doi: 10.26480/icemi.01.2017.250.253

Guba, E.G. (1981). Criteria for assessing the trustworthiness of naturalistic inquiries. *Educational Technology Research and Development, 29*(2), 75.

Habraken, M. (2016). *"Smart" work characteristics and outcomes for a Smart Industry context: A theoretical review* (Master degree, University of Groningen, the Netherlands), non-published work.

Habraken, M., & Bondarouk, T. (2017). Smart industry research in the field of HRM: Resetting job design as an example of upcoming challenges. In T. Bondarouk, H.J.M. Ruël, & E. Parry (Eds.), *Electronic HRM in the Smart Era* (pp. 221-259). Bingley, UK: Emerald Publishing Limited. doi: 10.1108/978-1-78714-315-920161009

Habraken, M., & Bondarouk, T. (2019). Smart Industry or smart bubbles? A critical analysis of its perceived value. In R. Bissola & B. Imperatori (Eds.), *HRM 4.0 For Human-Centered Organizations* (pp. 1-20). Bingley, UK: Emerald Publishing Limited. doi: 10.1108/S1877-636120190000023018

Habraken, M., Bondarouk, T., & Hoffmann, D. (2019). Shaking up the status quo? An analysis of developments in the social context of work stemming from Industry 4.0. In M. Coetzee (Eds.), *Thriving in Digital Workspaces*: *Emerging issues for research and practice* (pp. 197-216). Cham, Switzerland: Springer. doi: 10.1007/978-3-030-24463-7_10

Hackman, J.R., & Lawler, E.E. (1971). Employee reactions to job characteristics. *Journal of Applied Psychology, 55*(3), 259-286. doi: 10.1037/h0031152

Hackman, J.R., & Oldham, G.R. (1975). Development of the job diagnostic survey. *Journal of Applied psychology, 60*(2), 159-170. doi: 10.1037/h0076546

Hackman, J.R., & Oldham, G.R. (1976). Motivation through the design of work: Test of a theory. *Organizational Behavior and Human Performance, 16*(2), 250-279. doi: 10.1016/0030-5073(76)90016-7

Hamari, J., Koivisto, J., & Sarsa, H. (2014). *Does gamification work? - a literature review of empirical studies on gamification.* In *2014 47th Hawaii International Conference on System Sciences* (pp. 3025-3034). IEEE. doi: 10.1109/HICSS.2014.377

Hecklau, F., Galeitzke, M., Flachs, S., & Kohl, H. (2016). Holistic approach for human resource management in Industry 4.0. *Procedia CIRP, 54*, 1-6. doi: 10.1016/j.procir.2016.05.102

Hecklau, F., Orth, R., Kidschun, F., & Kohl, H. (2017). Human resources management: Meta-study-analysis of future competences in Industry 4.0. In *Proceedings of the 13th European Conference on Management, Leadership and Governance* (pp. 163-183).

Hermann, M., Pentek, T., & Otto, B. (2016). Design principles for Industrie 4.0 scenarious. In *2016 49th Hawaii International Conference on System Sciences* (pp. 3928-3937). IEEE. doi: 10.1109/HICSS.2016.488

Herzberg, F., Mausner, B., & Snyderman, B.B. (1959). *The motivation to work*. New York, NY: John Wiley & Sons.

Huizinga, G., Holterman, L., Kist, R., Bouws, T., Van der Beek, H., Wattel-Meijers, K., . . . Van der Mars, P. (2018). *Smart Industry Implementation Agenda 2018-2021*. Retrieved from https://smartindustry.nl/wp-content/uploads/2019/04/SI-Implementation-Agenda-2018-English.compressed.pdf

Huizinga, G., Walison, P., Bouws, T., Kramer, F., Van der Beek, H., Tops, P., . . . Grosfeld, T. (2014). *Smart Industry: Dutch industry fit for the future*. Retrieved from http://www.kennisbanksocialeinnovatie.nl/nl/kennis/kennisbank/smart-industry--dutch-industry-fit-for-the-future/1287?q

Humphrey, S.E., Nahrgang, J.D., & Morgeson, F.P. (2007). Integrating motivational, social, and contextual work design features: A meta-analytic summary and theoretical extension of the work design literature. *Journal of Applied Psychology, 92*(5), 1332-1356. doi: 10.1037/0021-9010.92.5.1332

Industrial revolution. (n.d.). In *Merriam-Webster Online.* Retrieved from https://www.merriam-webster.com/dictionary/industrial%20revolution

Kagermann, H., Wahlster, W., & Helbig, J. (2013). *Recommendations for implementing the strategic initiative Industrie 4.0. Final report of the Industrie 4.0 working group*. Retrieved from https://en.acatech.de/publication/recommendations-for-implementing-the-strategic-initiative-industrie-4-0-final-report-of-the-industrie-4-0-working-group/

Kang, H.S., Lee, J.Y., Choi, S., Kim, H., Park, J.H., Son, J.Y., . . . Do Noh, S. (2016). Smart manufacturing: Past research, present findings, and future directions. *International Journal of Precision Engineering and Manufacturing-Green Technology, 3*(1), 111-128. doi: 10.1007/s40684-016-0015-5

Kiggundu, M.N. (1981). Task interdependence and the theory of job design. *Academy of Management Review, 6*(3), 499-508. doi: 10.2307/257385

Kool, L., Van Est, R., Van Keulen, I., & Van Waes, A. (2015). Inleiding. In R. Van Est & L. Kool (Eds.), *Werken aan de robotsamenleving: Visies en inzichten uit de wetenschap over de relatie technologie en werkgelegenheid* (pp. 21-32). Den Haag, the Netherlands: Rathenau Instituut.

Krüger, L. (2018). *Developing an industry 4.0 framework: Implications for the role of line managers.* (Bachelor degree, University of Twente, the Netherlands). Retrieved from University of Twente theses database, http://purl.utwente.nl/essays/75440

Levy, F., & Murnane, R. (2013). *Dancing with robots: Human skills for computerized work*. Retrieved from http://www.thirdway.org/report/dancing-with-robots-human-skills-for-computerized-work

Liao, Y., Deschamps, F., Loures, E.d.F.R., & Ramos, L.F.P. (2017). Past, present and future of Industry 4.0 - a systematic literature review and research agenda proposal. *International Journal of Production Research, 55*(12), 3609-3629. doi: 10.1080/00207543.2017.1308576

Liden, R.C., Wayne, S.J., & Sparrowe, R.T. (2000). An examination of the mediating role of psychological empowerment on the relations between the job, interpersonal relationships, and work outcomes. *Journal of Applied Psychology, 85*(3), 407-416. doi: 10.1037//0021-9010.85.3.407

Machado, C.G., Winroth, M., Carlsson, D., Almström, P., Centerholt, V., & Hallin, M. (2019). Industry 4.0 readiness in manufacturing companies: Challenges and enablers towards increased digitalization. *Procedia CIRP, 81*, 1113-1118. doi: 10.1016/j.procir.2019.03.262

MacKenzie, S.B. (2003). The dangers of poor construct conceptualization. *Journal of the Academy of Marketing Science, 31*(3), 323-326. doi: 10.1177/0092070303254130

Madsen, D.Ø. (2019). The emergence and rise of Industry 4.0 viewed through the lens of management fashion theory. *Administrative Sciences, 9*(3), 71-95. doi: 10.3390/admsci9030071

Markoulli, M.P., Lee, C.I.S.G., Byington, E., & Felps, W.A. (2016). Mapping human resource management: Reviewing the field and charting future directions. *Human Resource Management Review, 27*(3), 367-396. doi: 10.1016/j.hrmr.2016.10.001

Miller, B., & Atkinson, R.D. (2013). *Are robots taking our jobs, or making them?* Retrieved from https://itif.org/publications/2013/09/09/are-robots-taking-our-jobs-or-making-them

Moktadir, A., Ali, S.M., Kusi-Sarpong, S., & Shaikh, A.A. (2018). Assessing challenges for implementing Industry 4.0: Implications for process safety and environmental protection. *Process Safety and Environmental Protection, 117*, 730-741. doi: 10.1016/j.psep.2018.04.020

Morgeson, F.P., & Campion, M.A. (2003). Work design. In W.C. Borman, D.R. Ilgen, & R.J. Klimoski (Eds.), *Handbook of Psychology: Industrial and Organizational Psychology* (Vol. 12 pp. 423-452). Hoboken, NJ: John Wiley & Sons.

Morgeson, F.P., Garza, A.S., & Campion, M.A. (2012). Work Design. In N. Schmitt & S. Highhouse (Eds.), *Handbook of Psychology: Industrial and Organizational Psychology* (Vol. 12, pp. 525-559). Hoboken, NJ: John Wiley & Sons. doi: 10.1002/9781118133880.hop212020

Morgeson, F.P., & Humphrey, S.E. (2006). The work design questionnaire (WDQ): Developing and validating a comprehensive measure for assessing job design and the nature of work. *Journal of Applied Psychology, 91*(6), 1321-1339. doi: 10.1037/0021-9010.91.6.1321

Morgeson, F.P., & Humphrey, S.E. (2008). Job and team design: Toward a more integrative conceptualization of work design. In M.J.J. (Eds.), *Research in Personnel and Human Resources Management* (Vol. 27, pp. 39-91). London, UK: Emerald Group Publishing Limited. doi: 10.1016/S0742-7301(08)27002-7

Müller, J.M., Buliga, O., & Voigt, K. (2018). Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. *Technological Forecasting and Social Change, 132*, 2-17. doi: 10.1016/j.techfore.2017.12.019

Müller, J.M., Kiel, D., & Voigt, K. (2018). What drives the implementation of Industry 4.0? The role of opportunities and challenges in the context of sustainability. *Sustainability, 10*(1), 247-271. doi: 10.3390/su10010247

Nahrgang, J.D., Morgeson, F.P., & Hofmann, D.A. (2011). Safety at work: A meta-analytic investigation of the link between job demands, job resources, burnout, engagement, and safety outcomes. *Journal of Applied Psychology, 96*(1), 71-94. doi: 10.1037/a0021484

Ohly, S., Sonnentag, S., & Pluntke, F. (2006). Routinization, work characteristics and their relationships with creative and proactive behaviors. *Journal of Organizational Behavior, 27*(3), 257-279. doi: 10.1002/job.376

Oldham, G.R., & Fried, Y. (2016). Job design research and theory: Past, present and future. *Organizational Behavior and Human Decision Processes, 136*, 20-35. doi: 10.1016/j.obhdp.2016.05.002

Oldham, G.R., & Hackman, J.R. (2010). Not what it was and not what it will be: The future of job design research. *Journal of Organizational Behavior, 31*(2-3), 463-479. doi: 10.1002/job.678

Orlikowski, W.J. (1992). The duality of technology: Rethinking the concept of technology in organizations. *Organization Science, 3*(3), 398-427. doi: 10.1287/orsc.3.3.398

Orzes, G., Rauch, E., Bednar, S., & Poklemba, R. (2018). Industry 4.0 Implementation Barriers in Small and Medium Sized Enterprises: A Focus Group Study. In *2018 IEEE International Conference on Industrial Engineering and Engineering Management* (pp. 1348-1352). IEEE. doi: 10.1109/IEEM.2018.8607477

Parker, S.K. (2014). Beyond motivation: Job and work design for development, health, ambidexterity, and more. *Annual Review of Psychology, 65*, 661-691. doi: 10.1146/annurev-psych-010213-115208

Parker, S.K., Wall, T.D., & Cordery, J.L. (2001). Future work design research and practice: Towards an elaborated model of work design. *Journal of Occupational and Organizational Psychology, 74*(4), 413-440. doi: 10.1348/096317901167460

Parker, S.K., & Zhang, F. (2016). Designing work that works in the contemporary world: Future directions for job design research. In A. Shimazu, R. Bin Nordin, M. Dollard, & J. Oakman (Eds.), *Psychosocial Factors at Work in the Asia Pacific: From theory to practice* (pp. 135-150). Cham, Switzerland: Springer. doi: 10.1007/978-3-319-44400-0_7

Pee, L.G., & Chua, A.Y.K. (2016). Duration, frequency, and diversity of knowledge contribution: Differential effects of job characteristics. *Information & Management, 53*(4), 435-446. doi: 10.1016/j.im.2015.10.009

Petrillo, A., de Felice, F., Cioffi, R., & Zomparelli, F. (2018). Fourth industrial revolution: Current practices, challenges, and opportunities. In A. Petrillo, R. Cioffi, & F. De Felice (Eds.), *Digital Transformation in Smart Manufacturing* (pp. 1-20). Rijeka, Croatia: Intech. doi: 10.5772/intechopen.72304

Pfeiffer, S. (2017). The vision of "Industrie 4.0" in the making - a case of future told, tamed, and traded. *NanoEthics, 11*(1), 107-121. doi: 10.1007/s11569-016-0280-3

Pistrui, J. (2018). *The future of human work is imagination, creativity, and strategy*. Retrieved from https://hbr.org/2018/01/the-future-of-human-work-is-imagination-creativity-and-strategy

Pluess, J.D. (2015). *Good jobs in the age of automation: Challenges and opportunities for the private sector*. Retrieved from https://www.bsr.org/en/our-insights/report-view/inclusive-economy-brief-jobs-and-automation

Podsakoff, P.M., MacKenzie, S.B., & Podsakoff, N.P. (2016). Recommendations for creating better concept definitions in the organizational, behavioral, and social sciences. *Organizational Research Methods, 19*(2), 159-203. doi: 10.1177/1094428115624965

Porter, M.E. (1979). How competitive forces shape strategy. *Harvard Business Review, 57*(2), 137-145.

Porter, M.E. (2008). The five competitive forces that shape strategy. *Harvard Business Review, 86*(1), 25-40.

Prifti, L., Knigge, M., Kienegger, H., & Krcmar, H. (2017). *A competency model for "Industrie 4.0" employees.* Paper presented at the 13th International Conference on Wirtschaftsinformatik, St Gallen, Switzerland.

Randstad. (2016). *Global report Randstad Workmonitor Q1, 2016: Technology and the human touch*. Retrieved from https://www.randstad.dk/om-os/presse/new-download-folder/workmonitor-2016-q1.pdf

Reischauer, G. (2018). Industry 4.0 as policy-driven discourse to institutionalize innovation systems in manufacturing. *Technological Forecasting and Social Change, 132*, 26-33. doi: 10.1016/j.techfore.2018.02.012

Rogers, E.M. (1983). *Diffusion of Innovations*. New York, NY: The Free Press.

Roulston, K., & Choi, M. (2018). Qualitative interviews. In U. Flick (Eds.), *The Sage handbook of qualitative data collection* (pp. 233-249). London, UK: Sage. doi: 10.4135/9781526416070.n15

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015). *Industry 4.0: The future of productivity and growth in* *manufacturing industries*. Retrieved from www.bcgperspectives.com/search/?SearchQuery=industry%204.0

Sailer, M., Hense, J., Mandl, H., & Klevers, M. (2017). Fostering development of work competencies and motivation via gamification. In M. Mulder (Eds.), *Competence-based Vocational and Professional Education* (pp. 795-818). Switzerland. Cham, Switzerland: Springer. doi: 10.1007/978-3-319-41713-4_37

Schattorie, J., De Jong, A., Fransen, M., & Vennemann, B. (2014). *De impact van automatisering op de Nederlandse arbeidsmarkt*. Retrieved from https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/deloitte-analytics/deloitte-nl-data-analytics-impact-van-automatisering-op-de-nl-arbeidsmarkt.pdf

Schouteten, R.L.J. (2015). Robotisering: Het kan, maar moet het ook? *Tijdschrift voor Arbeidsvraagstukken, 31*(2), 124-127. doi: 10.5553/TvA/016922162015031002003

Schuler, R.S. (1992). Strategic human resources management: Linking the people with the strategic needs of the business. *Organizational Dynamics, 21*(1), 18-32. doi: 10.1016/0090-2616(92)90083-Y

Shipp, A.J., Edwards, J.R., & Lambert, L.S. (2009). Conceptualization and measurement of temporal focus: The subjective experience of the past, present, and future. *Organizational Behavior and Human Decision Processes, 110*(1), 1-22. doi: 10.1016/j.obhdp.2009.05.001

Smetsers, D., & Borst, I. (2017). *Smart Industry onderzoek 2016*. Retrieved from https://www.kvk.nl/advies-en-informatie/innovatie/smart-industry/uitkomsten-onderzoek-smart-industry-2016/

Smith, A. (1776). *An inquiry into the nature and causes of the wealth of nations*. London, UK: W. Strahan & T. Cadell.

Smith, A. (2016). *Gig work, online selling and home sharing*. Retrieved from http://www.pewinternet.org/2016/11/17/gig-work-online-selling-and-home-sharing/

Stebbins, R.A. (2001). *Exploratory research in the social sciences*. Thousand Oaks, CA: Sage. doi: 10.4135/9781412984249

StratisticsNetherlands-CBS. (2019). Statline - Business; industry. https://opendata.cbs.nl/statline/#/CBS/nl/dataset/81589ned/line?dl=2901E&ts=1571393289656

Strohmeier, S. (2009). Concepts of e-HRM consequences: A categorisation, review and suggestion. *The International Journal of Human Resource Management, 20*(3), 528-543. doi: 10.1080/09585190802707292

Suddaby, R. (2010). Editor's comments: Construct clarity in theories of management and organization. *Academy of Management Review, 35*(3), 346-357. doi: 10.5465/amr.35.3.zok346

Taylor, F.W. (1911). *The principles of scientific management*. New York, NY: Norton.

Teamsmartindustry. (n.d.). Wiki Smart Industry. Retrieved from http://www.smartindustry.nl/wiki-smart-industry/

Ten Bulte, A. (2018). *What is Industry 4.0 and what are its implications on HRM practices?* (Bachelor degree, University of Twente, the Netherlands). Retrieved from University of Twente theses database, http://purl.utwente.nl/essays/75439

Ten Have, K., Van Rhijn, J.W., & Van Wijk, E.B. (2014). *Dilemma's in smart industry vragen om smart labour*. Retrieved from http://repository.tudelft.nl/view/tno/uuid%3A903c9ae8-4cd8-4151-884f-c3676efbd91d/

Turner, A.N., & Lawrence, P.R. (1965). *Industrial jobs and the worker*. Boston, MA: Harvard University.

Vacek, J. (2016). Socio-economic aspects of Industry 4.0. In *Innovation Management, Entrepreneurship and Corporate Sustainability* (pp. 731-741). Prague, Czech Republic: Vysoká škola ekonomická v Praze.

Van der Zee, F. (2015). Technologie en arbeidsproductiviteit. In R. Van Est & L. Kool (Eds.), *Werken aan de robotsamenleving: Visies en inzichten uit de wetenschap over de relatie technologie en werkgelegenheid* (pp. 93-110). Den Haag, the Netherlands: Rathenau Instituut.

Waschull, S., Bokhorst, J.A.C., & Wortmann, J.C. (2017). Impact of technology on work: Technical functionalities that give rise to new job designs in Industry 4.0. In *IFIP International Conference on Advances in Production Management Systems* (pp. 274-281). Cham, Switzerand: Springer. doi: 10.1007/978-3-319-66923-6_32

Whitmore, A., Agarwal, A., & Xu, L.D. (2015). The Internet of Things - A survey of topics and trends. *Information Systems Frontiers, 17*(2), 261-274. doi: 10.1007/s10796-014-9489-2

Witteman, J., & Heijne, S. (2014, October 1). 40 Procent banen op de tocht door opkomst robot. *de Volkskrant*. Retrieved from https://www.volkskrant.nl/nieuws-achtergrond/40-procent-banen-op-de-tocht-door-opkomst-robot~ba68fbf57/

Wright, B.M., & Cordery, J.L. (1999). Production uncertainty as a contextual moderator of employee reactions to job design. *Journal of Applied Psychology, 84*(3), 456-463. doi: 10.1037/0021-9010.84.3.456

Appendices

Appendix A. Definitions of job characteristics (Chapter 2)

Table A.1 Adopted definitions of job characteristics

Category	Job characteristic	Definition
TASK	Task significance	"the degree to which a job influences the lives or work of others, whether inside or outside the organisation"
	Task identity	"the degree to which a job involves a whole piece of work, the results of which can be easily identified"
	Task variety	"the degree to which a job requires employees to perform a wide range of tasks on the job"
	Autonomy	"the extent to which a job allows freedom, independence, and discretion to schedule work, make decisions, and choose the methods used to perform tasks"
	Feedback from job	"the degree to which carrying out the work activities required by the job results in the individual obtaining direct and clear information about the effectiveness of his or her performance"
SOCIAL	Feedback from others	"the degree to which others in the organisation provide information about performance"
	Interaction outside firm	"the extent to which the job requires employees to interact and communicate with individuals external to the organisation"
	Social support	"the degree to which a job provides opportunities for advice and assistance from others"
	Task interdependence	"the degree to which the job depends on others and others depend on it to complete the work"
KNOWLEDGE	Skill variety	"the extent to which a job requires an individual to use a variety of different skills to complete the work"
	Job complexity	"the extent to which the tasks on a job are complex and difficult to perform"
	Problem solving	"the degree to which a job requires unique ideas or solutions and reflects the more active cognitive processing requirements of a job"
	Information processing	"the degree to which a job requires attending to and processing data or other information"

	Specialisation	"the extent to which a job involves performing specialized tasks or possessing specialized knowledge and skill"
CONTEXTUAL	Work conditions	"the environment within which a job is performed"
	Physical demands	"the level of physical activity or effort required in the job"
	Ergonomics	"the degree to which a job allows correct or appropriate posture and movement"
	Equipment use	"the variety and complexity of the technology and equipment used in a job"
UNCLASSIFIED	Attentional demands	"the degree to which constant monitoring of work is required" (Morgeson & Campion, 2003, p.434)
	Production responsibility	"the extent to which an individual can make errors that can result in costly losses of output" (Morgeson & Campion, 2003, p.434)
	Emotional labour or demands	"a requirement for individuals to manage their emotional expression in return for wage" (Parker et al., 2001, p.423)

Notes: Definitions stem from Humphrey et al. (2007, pp. 1323-1324) unless otherwise indicated. Included papers provided no definition for: opportunity for skill acquisition, role conflict, home-work conflict, virtual work, skill and ability requirements, workday cycles, temporal horizon and time pressure.

Appendix B. Information on respondents (Chapter 3)

Table B.1 Sector and origin information of respondents

Sector	Number of respondents	Origin
Chemical	1	Forum
Educational institution	1 University	Forum
	2 Universities of applied sciences	Forum & Recommendation
Employers organisation (FME)	1	Recommendation
Food	2	Forum
Government	1 National	Forum
	1 Province	Forum
IT	2	Forum
Knowledge institution (TNO)	3	Forum & Recommendations
Life science & health	2	Forum
Metal	1	Forum
Partnerships	2	Forum & Recommendation
Water & shipbuilding	1	Forum

Appendix C. Interview protocol (Chapter 4)

Name of interviewee: Date:
Location: Function:
Start time of interview: End time of interview:
Specifics:

Introduction

Aim: *get to know interviewee, introduce purpose of the interview & mention their rights*

Address:

- Introduction of interviewer
- Research set-up
- Rights of interviewee
- Informed consent
- Introduction of interviewee (function, work experiences, work activities)

Topic X – 1. Feedback from others; 2. Social support; 3. Interaction outside the organisation and 4. Interdependence

Aim: *to gain insights into the experience of characteristic X at the moment and to reflect on the changes in relation to the past, specifically the influence of technology. A standard question for each subject is: "how does this happen?" and / or "what does this look like?"*

Questions:

- How has X changed in the past 5 years? [explain the respective characteristic when necessary]
- In what way has technology played a role in this change?
  - When mentioning Smart Industry (SI) > inquire about the different technologies & dive into specifics regarding changes of the characteristic and respective SI technologies
  - When SI is not mentioned > search for the cause of change and link to SI when possible

NOTE: when interviewee was an employee, questions adopted the standpoint of their own work. When interviewee was a manager, questions adopted a 'group perspective' (i.e. the department they managed).

Closing
Address possibility for respondent to reflect/offer feedback on their answers
Thank you

Appendix D. Reference information regarding case data (Chapter 5)

AEBI SCHMIDT

- Eastern Dutch, regional, platform for Industry 4.0 – Boost AS, 2017
  https://smartindustryoost.nl//wp-content/uploads/2016/12/Interview-met-Fred-Harbers.pdf
- Dutch national platform for Industry 4.0
  https://smartindustry.nl/wiki-smart-industry/voorbeelden-van-ondernemers/aebi-schmidt/
- Other interview source – Link Magazine, 2017
  https://www.linkmagazine.nl/minder-zout-meer-data/
- Additional information – PIANOO, 2019
  https://www.pianoo.nl/en/public-procurement-netherlands
- Reference used to assess number of employees
  https://www.wv-hig.nl/leden/aebi-schmidt-nederland-bv/

BRUIL

- Eastern Dutch, regional, platform for Industry 4.0 – Boost B, 2017
  https://smartindustryoost.nl//wp-content/uploads/2016/12/Interview-met-Theo-Voogd.pdf
- Website links – respectively News Nov. 2015 and Dec. 2018
  https://www.bruil.nl/over-ons/actuele-berichten/bruil-ontwikkelt-3d-printer-voor-architectonisch-beton

  https://www.bruil.nl/over-ons/actuele-berichten/kansen-van-digitalisering
- Non-referenced, but used website links
  https://www.bruil.nl/over-ons/actuele-berichten/bruil-zet-in-op-innovatie

  https://www.bruil.nl/over-ons/actuele-berichten/3d-geprint-architectonisch-beton-op-material-xperience-2016

  https://www.bruil.nl/over-ons/actuele-berichten/bruil-prefab-printing-van-lab-naar-fabriek
- Reference used to assess number of employees
  https://www.debanensite.nl/vacatures/bruil

DE CROMVOIRTSE

- Dutch national platform for Industry 4.0
  https://smartindustry.nl/wiki-smart-industry/voorbeelden-van-ondernemers/cromvoirtse/
- Other interview source – Van Ede, 2015
  https://www.procesverbeteren.nl/smart_industry/De_Cromvoirtse_Smart_Industry.php
- Website link – About us, 2019
  https://decromvoirtse.nl/over-ons/
- Reference used to assess number of employees
  https://www.promotietechniekmb.nl/de-cromvoirtse/

GS METAAL

- Dutch national platform for industry
  https://smartindustry.nl/wiki-smart-industry/voorbeelden-van-ondernemers/gs-metaal/
- Other interview source – Link Magazine, 2018
  https://www.linkmagazine.nl/gs-metaal-bouwt-samen-met-trumpf-digital-factory-voor-zichzelf-en-concullegas/
- Website links – respectively News Nov. 2018 and Feb. 2019
  https://www.gsmetaal.nl/lean-training/
  https://www.gsmetaal.nl/stap-stap-naar-digitale-transformatie/
- Additional information – Burgering & Kemps, 2016
  https://insights.abnamro.nl/branche/metaalproductenindustrie/
- Reference used to assess number of employees
  https://www.gsmetaal.nl/bedrijfsprofiel/

HOUSE OF BLUE JEANS

- Dutch national platform for Industry 4.0 – National platform_HBJ, n.d.
  https://www.smartindustry.nl/wiki-smart-industry/voorbeelden-van-ondernemers/titel-house-of-blue-jeans-gemak-groot-pluspunt-van-tech/
- Non-referenced, but used video link (obtained from House of Blue Jeans Facebook)
  https://www.youtube.com/watch?v=XzjMRP4DSBo

ITTER

- Dutch national platform for Industry 4.0 – National platform_I, n.d.
  https://smartindustry.nl/wiki-smart-industry/voorbeelden-van-ondernemers/itter/
- Eastern Dutch, regional, platform for Industry 4.0 – Boost_I, 2018
  https://smartindustryoost.nl/uploads/Nieuws/Itter%20BOOST.pdf
- Website links – respectively Automation, n.d. and Employees, n.d.
  https://www.itter.nl/machines/automatisering
  https://www.itter.nl/over-itter/medewerkers
- Reference used to assess number of employees
  https://www.itter.nl/over-itter/medewerkers

KORNELIS CAPS & CLOSURES

- Eastern Dutch, regional, platform for Industry 4.0 – Boost_KCC, 2018
  https://smartindustryoost.nl/uploads/Nieuws/interview%20met%20Ytsen%20de%20Boer%20.pdf
- Grant application link – RVO, 2016
  https://www.rvo.nl/subsidies-regelingen/projecten/smart-factory

- Other interview source – Verpakkingsmanagement, 2017
  https://www.verpakkingsmanagement.nl/kornelis-transitie-naar-smart-factory
- Reference used to assess number of employees
  https://meppelercourant.nl/artikel/465307/groeiende-omzet-bij-kornelis-vraagt-om-versnelde-uitvoering-nieuwbouwplannen.html?harvest_referrer=https%3A%2F%2Fwww.google.com%2F

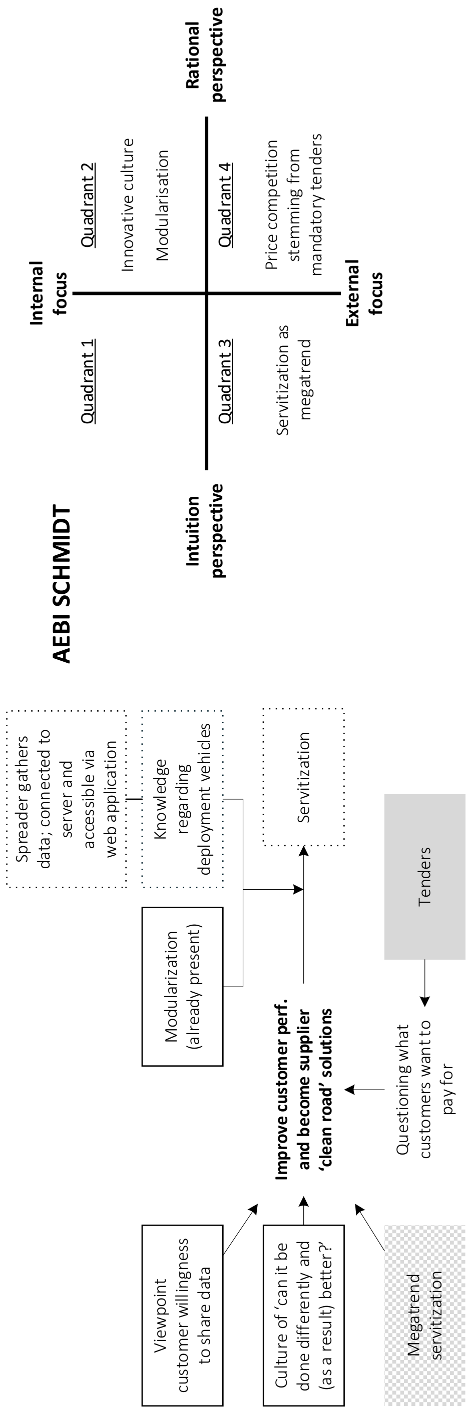
VAN RAAM RIJWIELEN

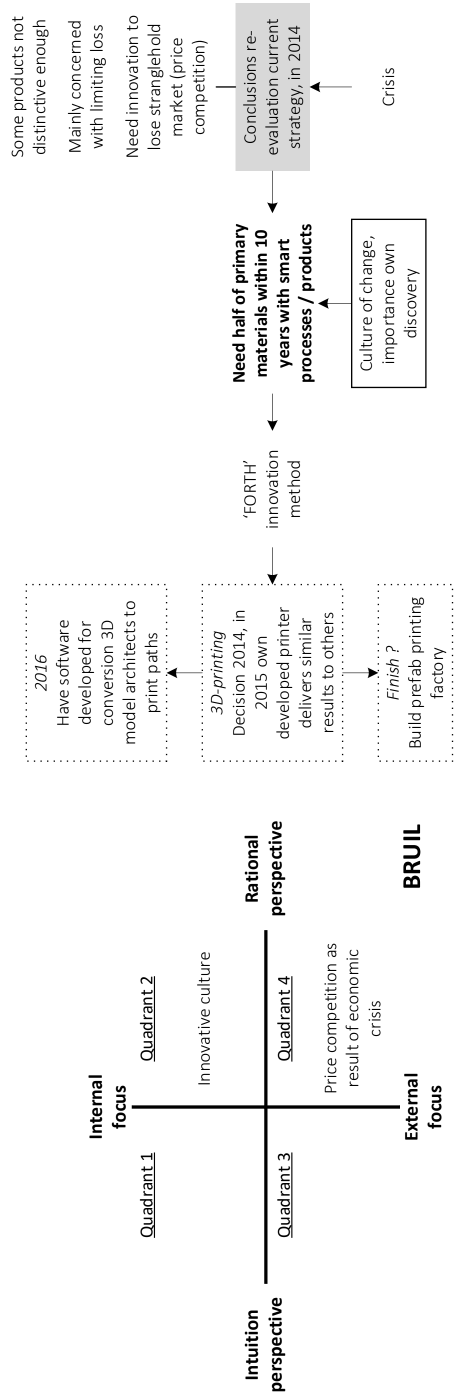
- Dutch national platform for Industry 4.0
  https://smartindustry.nl/wiki-smart-industry/voorbeelden-van-ondernemers/van-raam/

  > especially the included video – Smart Industry, Jan. 2017:
  https://www.youtube.com/watch?time_continue=2&v=wwM_t0pMUqY
- Eastern Dutch, regional, platform for Industry 4.0 – Boost_VRR, 2017
  https://smartindustryoost.nl//wp-content/uploads/2016/12/Interview-met-Marjolein-Boezel.pdf
- Video by Province of Gelderland – Province of Gelderland, Jan. 2019 (via Van Raam)
  https://vimeo.com/311636926
- Additional information – respectively Link magazine, 2016 & Smarthubacademy, n.d.
  https://www.linkmagazine.nl/boost-smart-industry-oost-nederland/

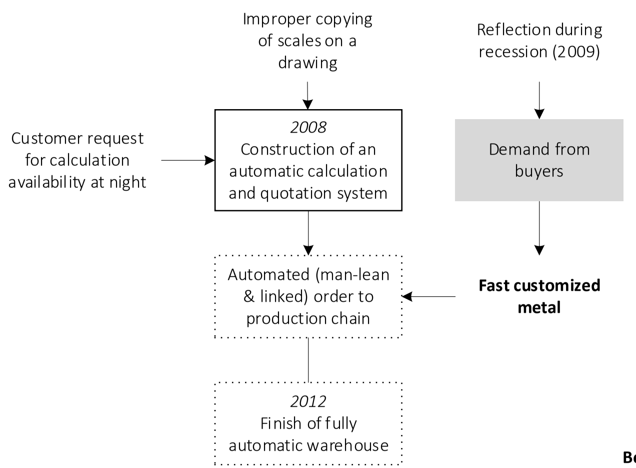
  http://www.smarthubacademy.nl/masterclasses/programma/
- Non-referenced, but used website link
  https://www.vanraam.com/nl-nl/over-van-raam/innovatie
- Reference used to assess number of employees
  https://www.vanraam.com/nl-nl/over-van-raam/over-ons

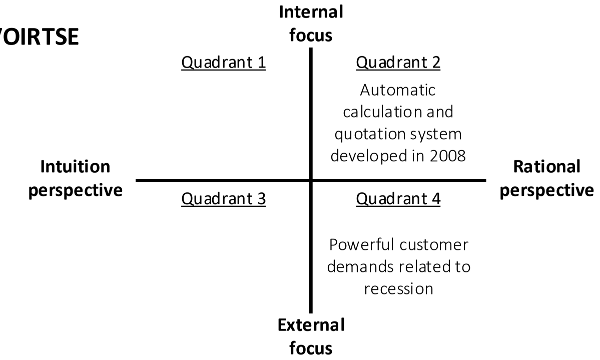
Appendix E. Case specific flow charts and frameworks (Chapter 5)



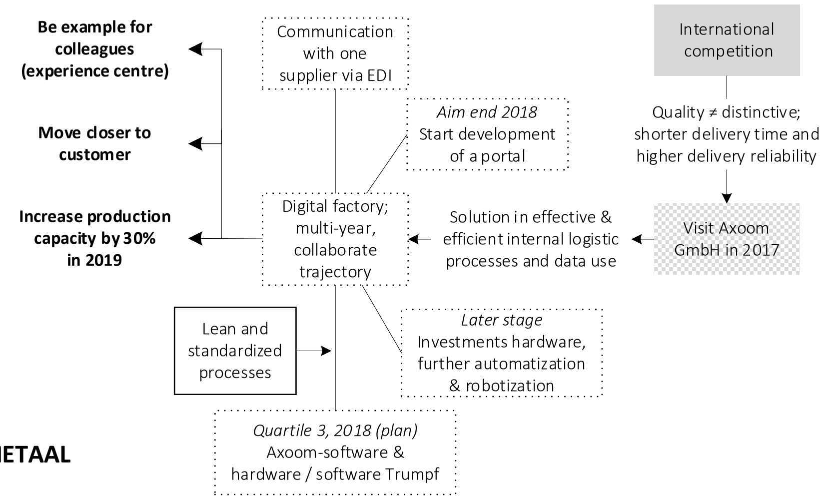


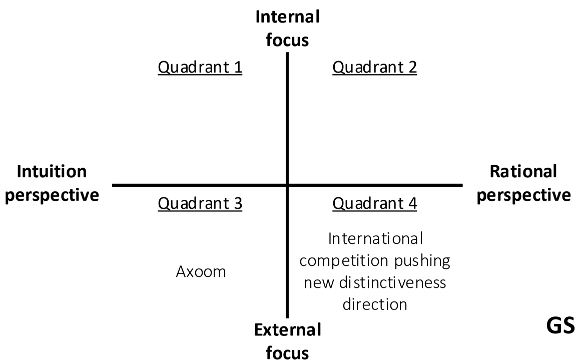
DE CROMVOIRTSE

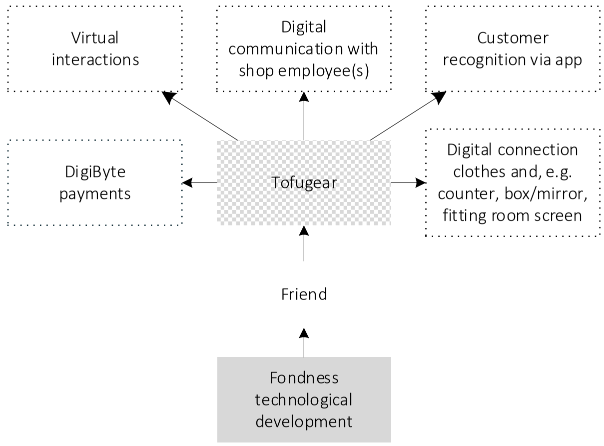




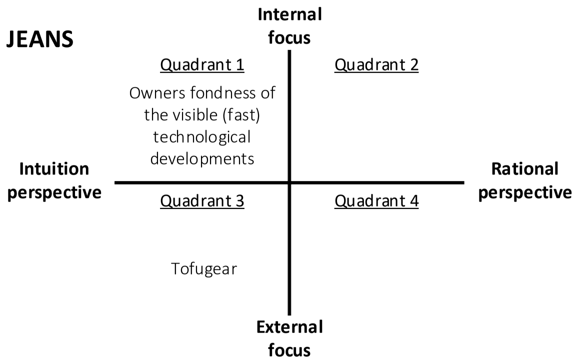
GS METAAL

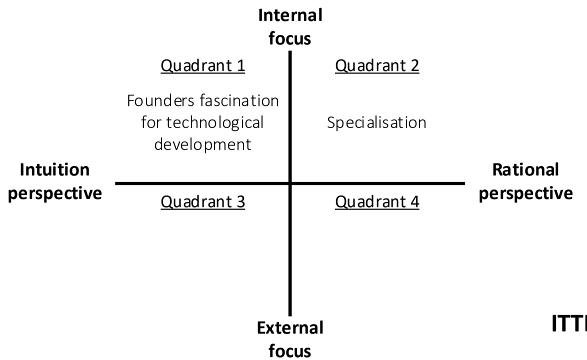




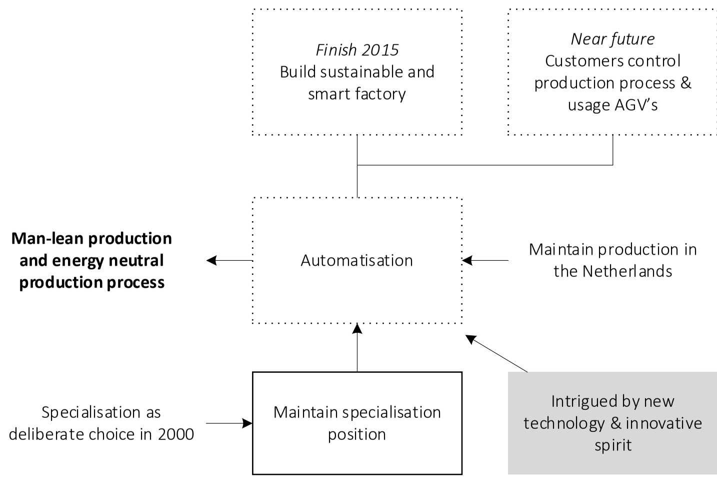


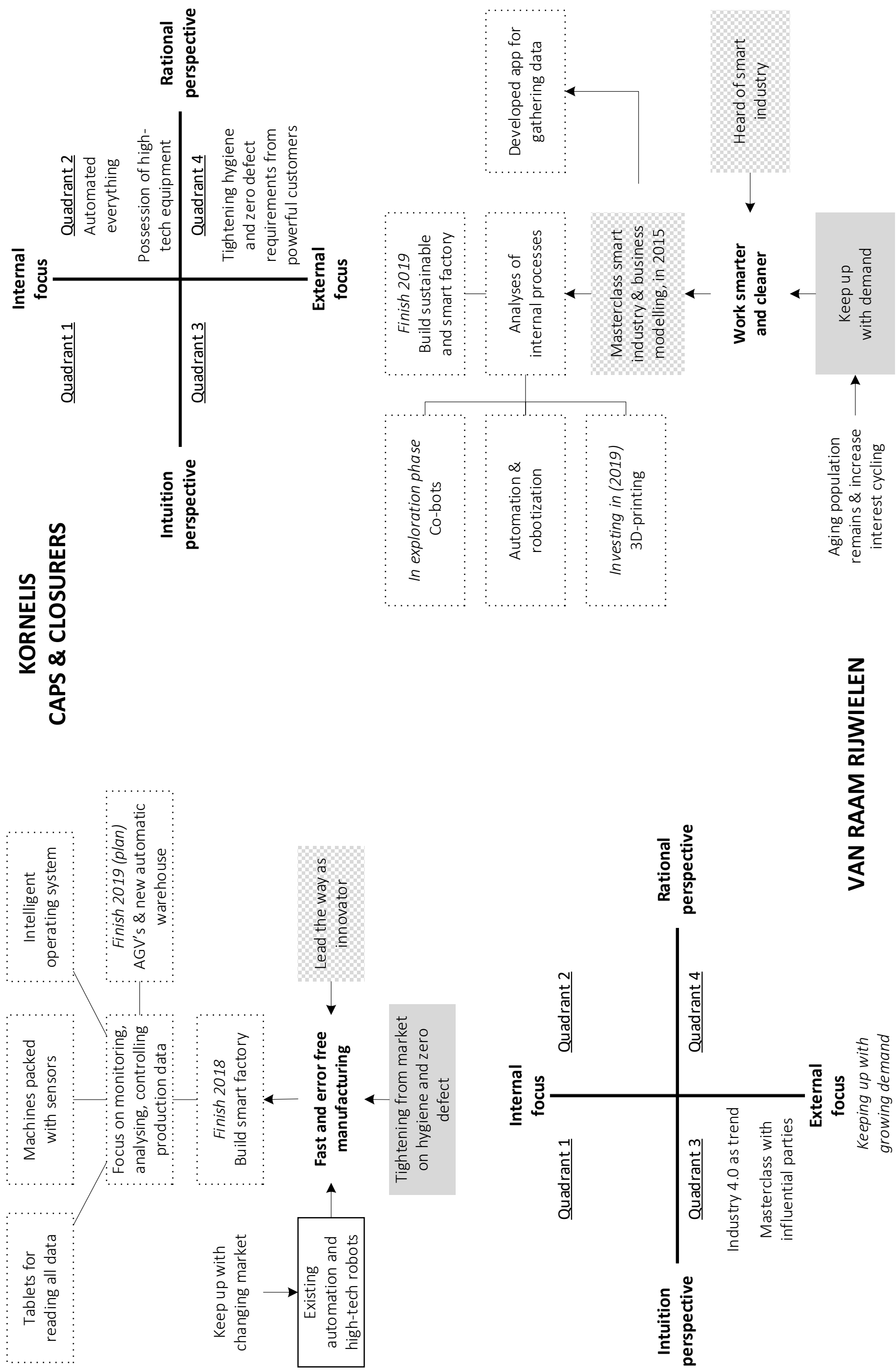
HOUSE OF BLUE JEANS





ITTER




KORNELIS
CAPS & CLOSURERS
Internal focus
External focus
Intuition perspective
Rational perspective
Quadrant 1
Quadrant 2
Automated everything
Possession of high-tech equipment
Quadrant 3
Quadrant 4
Tightening hygiene and zero defect requirements from powerful customers
Tablets for reading all data
Machines packed with sensors
Intelligent operating system
Focus on monitoring, analysing, controlling production data
Finish 2019 (plan) AGV's & new automatic warehouse
Finish 2018 Build smart factory
Keep up with changing market
Existing automation and high-tech robots
Fast and error free manufacturing
Lead the way as innovator
Tightening from market on hygiene and zero defect
VAN RAAM RIJWIELEN
Internal focus
External focus
Keeping up with growing demand
Intuition perspective
Rational perspective
Quadrant 1
Quadrant 2
Quadrant 3
Quadrant 4
Industry 4.0 as trend
Masterclass with influential parties
In exploration phase Co-bots
Automation & robotization
Investing in (2019) 3D-printing
Finish 2019 Build sustainable and smart factory
Analyses of internal processes
Developed app for gathering data
Masterclass smart industry & business modelling, in 2015
Work smarter and cleaner
Heard of smart industry
Keep up with demand
Aging population remains & increase interest cycling

Appendix F. Development of job design characteristics (Chapter 6)

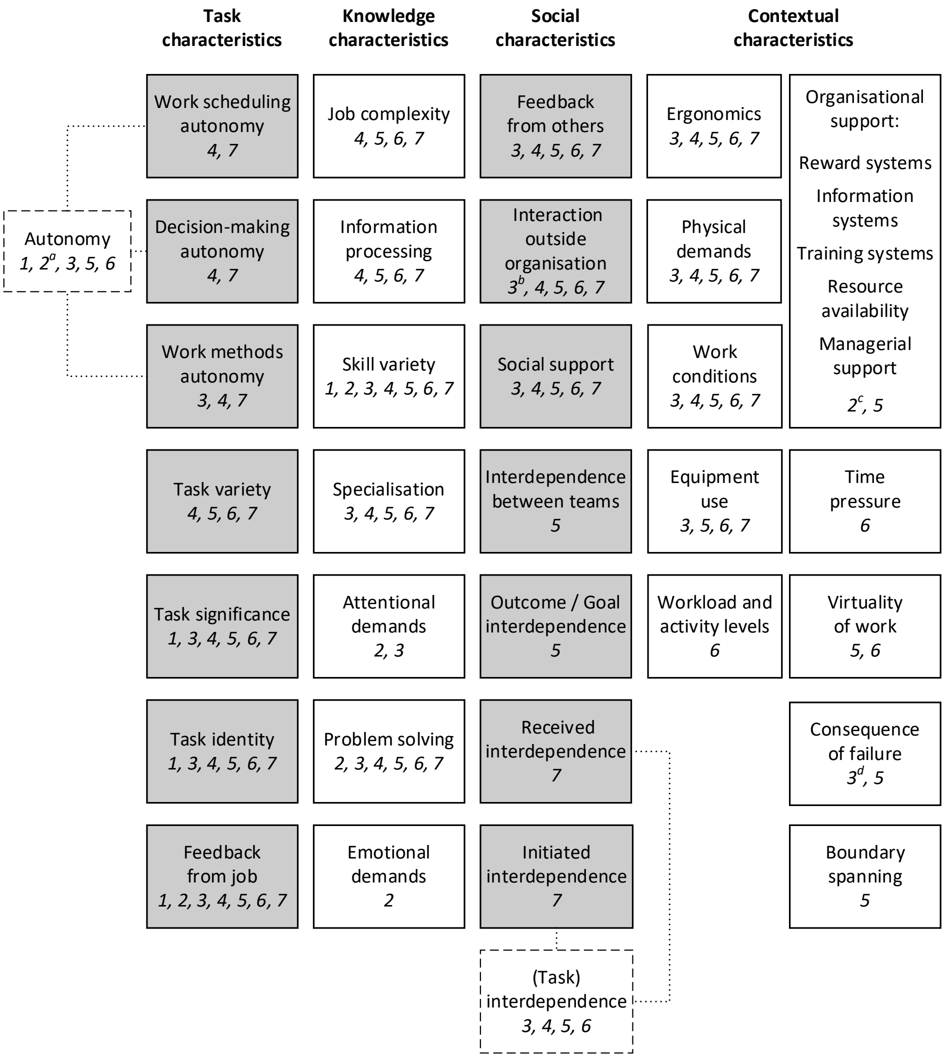


Figure F.1 An integrated overview of characteristics in existing job design models

Notes: Numbers illustrate the source(s): **1.** Hackman and Oldham (1976); **2.** Parker et al. (2001); **3.** Morgeson and Campion (2003); **4.** Humphrey et al. (2007); **5.** Morgeson and Humphrey (2008); **6.** Grant et al. (2011); **7.** Morgeson et al. (2012).

The letters imply the following: **a.** Parker et al. (2001) incorporated 'job control'; **b.** Morgeson & Campion (2003) incorporated 'dealing with others'; **c.** Parker et al. (2001) incorporated a related characteristic 'opportunity for skill acquisition'; **d.** Morgeson & Campion (2003) incorporated a similar characteristic 'production responsibility'.

Summary

Back in 2015, Industry 4.0 was a relatively new concept receiving limited attention that was primarily technical in nature. However, there were signs indicating it would become an important phenomenon for the social sciences, resulting in the motive to build an Industry 4.0 human resource management (HRM) knowledge base. Over time, the Industry 4.0 phenomenon turned out to be anything but clear. Therefore, the studies reported in this dissertation either examine the phenomenon itself or address the manner in which Industry 4.0 influences HRM, or specifically job design. As a result, this dissertation addresses two interrelated main research questions: 1) '*What does the Industry 4.0 phenomenon entail?*' and 2) '*In what way does Industry 4.0 affect job design?*' In answering these questions, this dissertation includes **four studies**.

The **first study** concerns the lack of HRM-related research on Industry 4.0. It highlights the importance of raising questions and conducting research on Industry 4.0 from an HRM perspective. First, we strengthen our call for more HRM-related research into Industry 4.0 by discussing and indicating our position in the employment debate that was raging at that time. Next, upcoming issues arising from Industry 4.0 are predicted using a job design lens. By combining our understanding of the phenomenon with a self-constructed overview of research on job design, we developed challenges that were seen as a non-exhaustive list of some of the impacts of Industry 4.0.

The **second study** focuses on the observed lack of clarity surrounding the meaning of, and diversity in, labels linked to the Industry 4.0 phenomenon. It examines the value of the Dutch Smart Industry label by developing an understanding of this label, which enabled us to compare it with the more general term 'fourth industrial revolution' as well as existing interpretations of Industry 4.0. The comparison shows considerable overlap between the Dutch Smart Industry label and the Industry 4.0 label, which strengthens our call to combine forces. That is, it offers evidence that the diversity in labels does not serve an essential purpose for academia. Due to the communicative component, the Smart Industry label was considered to remain relevant for practice.

The **third study** focuses on an essential but unexplored job characteristic concerning Industry 4.0. It analyses the developments that can be observed with respect to the social context of work as a result of the Industry 4.0 work context.

The findings emphasise the value of face-to-face communication and show that both digital and social means of interaction appear to have different purposes. In addition, the results reveal two ways in which Industry 4.0 influences the social context of work: (1) it leads to changes in the intensity and/or source of existing social characteristics, and (2) introduces new structures (a lending system) or emphasises known ones (teams).

The fourth study, given the slow adoption of Industry 4.0, attempts to expand the current implementation-oriented approach by shifting the focus to a preceding step – the decision-making phase. To do so, an Industry 4.0 strategic decision-making (SDM) typology framework is developed. A cross-case analysis of empirical data shows that the decision-making process surrounding Industry 4.0 is driven by various motives. Results further indicate that the four identified quadrants never act alone, suggesting that there are two different roles in the Industry 4.0 decision-making process: motives addressing why (prime movers) and those facilitating the direction (necessary facilitators). Both roles appear essential to arrive at an Industry 4.0 adoption decision, thereby emphasising that the decision-making process should not be underestimated or neglected.

By integrating the studies 2 and 4, both theory and practice gain an increased understanding of Industry 4.0. The phenomenon is identified as a broad, overarching concept that overlaps with the Dutch Smart Industry label. Given the operational impracticability of such breadth, an operational solution is proposed. Besides the meaning of Industry 4.0, its adoption is also shown to be highly complex. Not only are implementation issues such as financial or cultural barriers relevant, but adoption also appears to be hindered if motives within either the prime movers or necessary facilitators category are lacking. Studies 1 and 3 further contribute to theory and practice with insights from a job design perspective into the effects of Industry 4.0. We show that feedback from the job will become more data-driven; that interactions outside the organisation will increase in relevance and can expand in terms of the types of contacts, and that the underexposed dimensions of interdependence (i.e. between teams or in terms of outcomes and goals) remain important and deserve greater recognition. Finally, the dissertation offers directions for future research that can generate additional practical support and expand the topic academically as Industry 4.0 continues to evolve.

Samenvatting

Industry 4.0 was in 2015 een relatief nieuw concept dat beperkte aandacht kreeg, die voornamelijk technisch van aard was. Er waren echter tekenen die erop wezen dat het een belangrijk fenomeen voor de sociale wetenschappen zou worden, wat leidde tot het motief om een Industry 4.0 human resource management (HRM) kennisbank te ontwikkelen. Na verloop van tijd bleek het fenomeen Industry 4.0 echter allesbehalve duidelijk. Daarom richten de studies in dit proefschrift zich naast de manier waarop Industry 4.0 HRM beïnvloedt, of specifieker gezegd job design, ook op het fenomeen zelf. Zodoende omvat dit proefschrift twee onderling samenhangende hoofdvragen: 1) '*Wat houdt het fenomeen Industry 4.0 in?*' En 2) '*Op welke manier heeft Industry 4.0 invloed op job design?*' Dit proefschrift bestaat uit vier verschillende studies om tot een antwoord op deze twee vragen te komen.

De **eerste studie** richt zich op het gebrek aan HRM-gerelateerd onderzoek naar Industry 4.0. Het benadrukt het belang van het stellen van vragen en het uitvoeren van onderzoek naar Industry 4.0 vanuit een HRM-perspectief. Ten eerste versterken we onze roep voor meer HRM-gerelateerd onderzoek naar Industry 4.0 door de werkgelegenheidsdiscussie, die toen hevig woedde, te bespreken en onze positie daarin aan te geven. Vervolgens worden er verscheidene uitdagingen aangekaart, vanuit een job design lens, die ontstaan als gevolg van Industry 4.0. Door ons begrip van het fenomeen te combineren met een zelf geconstrueerd overzicht van onderzoek rond job design, ontwikkelden we uitdagingen die gezien moeten worden als een niet-uitputtende lijst van enkele van de effecten van Industry 4.0.

De **tweede studie** richt zich op het waargenomen gebrek aan duidelijkheid over de betekenis van, en diversiteit in labels die verband houden met het fenomeen Industry 4.0. Het onderzoekt de waarde van het Nederlandse Smart Industry-label door een begrip van dit label te ontwikkelen, waardoor we het konden vergelijken met de meer algemene term 'vierde industriële revolutie' en bestaande interpretaties van Industry 4.0. De vergelijking toont een aanzienlijke overlap aan tussen het Nederlandse Smart Industry-label en het label Industry 4.0. Dit versterkt onze roep om krachten te bundelen. Dat wil zeggen, het biedt bewijs dat de diversiteit in labels geen essentieel doel dient voor de

academische wereld. Vanwege het communicatieve component van dit fenomeen wordt het label Smart Industry wel relevant geacht voor de praktijk.

De **derde studie** richt zich op een essentiële maar onontgonnen baankarakteristiek (de 'social characteristics') met betrekking tot Industry 4.0. Het analyseert de ontwikkelingen die kunnen worden waargenomen ten aanzien van de sociale context van werk, als gevolg van Industry 4.0. De bevindingen benadrukken de waarde die persoonlijke communicatie bezit, en geven aan dat zowel digitale als sociale interacties verschillende doelen lijken te hebben. Bovendien onthullen de resultaten twee manieren waarop Industry 4.0 de sociale context van werk beïnvloedt: (1) het leidt tot veranderingen in de intensiteit en / of bron van bestaande 'social characteristics', en (2) introduceert nieuwe structuren (een leensysteem) of benadrukt bekende structuren (teams).

Gezien de trage introductie van Industry 4.0, probeert de **vierde studie** de huidige implementatiegerichte aanpak uit te breiden door de focus te verleggen naar een voorafgaande stap - de besluitvormingsfase. Om dit te bereiken, is een Industry 4.0 strategisch besluitvorming (SDM) typologie raamwerk ontwikkeld. Een cross-case analyse van de empirische data laat zien dat het besluitvormingsproces rond Industry 4.0 wordt aangedreven door diverse motieven. De resultaten geven verder aan dat de vier geïdentificeerde kwadranten nooit alleen handelen, wat suggereert dat er twee verschillende rollen zijn in het besluitvormingsproces van Industry 4.0: motieven die het waarom aankaarten ('prime movers') en motieven die de richting faciliteren ('necessary facilitators'). Beide rollen lijken essentieel om te komen tot een besluit rond de introductie van Industry 4.0, waarmee wordt benadrukt dat het besluitvormingsproces niet moet worden onderschat of verwaarloosd.

Door de kennis van studies 2 en 4 te integreren, krijgt zowel de theorie als de praktijk een beter begrip van Industry 4.0. Het fenomeen wordt geïdentificeerd als een breed, overkoepelend concept dat overlapt met het Nederlandse Smart Industry-label. Gezien de operationele onuitvoerbaarheid van een dergelijke breedte wordt een operationele oplossing voorgesteld. Naast de betekenis van Industry 4.0, is de introductie ervan ook zeer complex gebleken. Niet alleen zijn uitvoeringskwesties zoals financiële of culturele barrières relevant, maar de introductie lijkt ook te worden belemmerd als er geen motieven zijn binnen de categorie 'prime movers' of 'necessary facilitators’. Studies 1 en 3 dragen verder bij aan de theorie en praktijk met het bieden van inzichten in de effecten van Industry 4.0 vanuit een job design lens. We laten zien dat ‘feedback from the job’ meer data gedreven wordt; dat ‘interactions outside the organisation’ relevanter wordt en kan uitbreiden qua soort contacten, en dat de onderbelichte dimensies van ‘interdependence’ (d.w.z. onderlinge afhankelijkheid tussen teams of in termen van resultaten en doelen) belangrijk blijven en meer erkenning verdienen. Ten slotte biedt dit proefschrift mogelijkheden voor toekomstig onderzoek waardoor extra praktische ondersteuning gegenereerd kan worden en het onderwerp academisch kan uitbreiden naarmate Industry 4.0 verder evolueert.

About the author

Milou Habraken was born on the 3rd of April 1989 in Valkenswaard, the Netherlands. In 2007, she moved to the region of Twente to start her university education. At the University of Twente, she obtained a Bachelor of Science and a Master of Science degree in Business Adminstration. Within the last years of her bachelor study, Milou was a student assistant for a course on organisation theory. After her master studies, she held an HR function at Landgoedhotel De Wilmersberg. The hotel within which she also conducted her master thesis.

To develop her growing interest for a PhD position, Milou moved to Groningen to follow the two year research master in Economics and Business program (profile Human Resource Management and Organisational Behaviour) at the University of Groningen. After completing the first year, Milou was able to start a PhD project on Smart Industry, or Industry 4.0, at the University of Twente in the Human Resource Management department. As a result, she returned to the region of Twente and combined the first year of her PhD project with finalising the Research Master from Groningen; leading to her Master of Science degree in Economics and Business (research).

Over the course of her PhD, Milou published her research in the books *Electronic HRM in the Smart Era*, *Thriving in Digital Workspaces* and *HRM 4.0 for Human-Centred Organisations*. Further, as a result of her second study, Milou contributed to the *Smart Industry roadmap: Onderzoeksagenda voor HTSM en ICT en routekaart voor de NWA* (2018). She also presented her research at international conferences, including the International e-HRM Conference (2016 and 2018), the International Conference of the Dutch HRM Network (2017 and 2019), the Work2017 Conference (2017) and the HRM Division International Conference (2019). In addition, she co-organised a sympomosium with Prof. dr. Tanya Bondarouk (2018).

Besides her research, Milou taught the minor module High Tech Talent Management in a Global Context, provided guest lectures on Smart Industry and HRM to third year International HRM students of Saxion Univeristy of Applied Sciences and supervised several Bachelor and Master students.

She currently works as a postdoctoral researcher at the University of Twente, in the Human Resource Management department.

Back in 2015, Industry 4.0 was a relatively new concept receiving limited attention that was primarily technical in nature. However, there were signs indicating it would become an important phenomenon for the social sciences, resulting in the motive to build an Industry 4.0 human resource management (HRM) knowledge base. Over time, Industry 4.0 turned out to be anything but clear. Therefore, the studies reported in this dissertation either examine the phenomenon itself or address the manner in which Industry 4.0 influences HRM, or specifically job design. As a result, this dissertation addresses two interrelated main research questions: 1) 'What does the Industry 4.0 phenomenon entail?' and 2) 'In what way does Industry 4.0 affect job design?'

The results of explorative qualitative research show that Industry 4.0 is identified as a broad, overarching concept that overlaps with the Dutch Smart Industry label. Given the operational impracticability of such breadth, an operational solution is proposed. Besides the meaning of Industry 4.0, its adoption is also shown to be highly complex. Not only are implementation issues such as financial or cultural barriers relevant, but adoption also appears to be hindered if motives within either the prime movers or necessary facilitators category are lacking. Regarding the effects of Industry 4.0 on job design, results show that feedback from job will become more data driven; that interactions outside the organisation will increase in relevance and expand in content, and that the underexposed dimensions of interdependence remain important and deserve greater recognition.