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Paradoxical tensions during industry 4.0 integration within health care: managing tensions for quality improvement

Daan Kabel, Jason Martin and Mattias Elg
Department of Management and Engineering, Linköping University, Linkoping, Sweden

Abstract

Purpose – The integration of industry 4.0 has become a priority for many organizations. However, not all organizations are suitable and capable of implementing industry 4.0 because it requires a dynamic and flexible implementation strategy. The implementation of industry 4.0 often involves overcoming several tensions between internal and external stakeholders. This paper aims to explore the paradoxical tensions that arise for health-care organizations when integrating industry 4.0. Moreover, it discusses how a paradox lens can support the conceptualization and proposes techniques for handling tensions during the integration of industry 4.0.

Design/methodology/approach – This qualitative and in-depth study draws upon 32 semi-structured interviews. The empirical case concerns how two health-care organizations handle paradoxical tensions during the integration of industry 4.0.

Findings – The exploration resulted in six recurring technology tensions: technology invention (modularized design vs. flexible design), technology collaboration (automation vs. human augmentation), technology-driven patient experience (control vs. autonomy), technology uncertainty (short-term experimentation vs. long-term planning), technology invention and diffusion through collaborative efforts among stakeholders (selective vs. intensive collaboration) and technological innovation (market maintenance vs. disruption).

Originality/value – A paradox theory-informed conceptual model is proposed for how to handle tensions during the integration of industry 4.0. To the best of the authors' knowledge, this is the first paper to introduce paradox theory for quality management, including lean and Six Sigma.

Keywords Industry 4.0, Digitalization, Health care, Digital technology, Quality management, Strategy

Paper type Research paper

1. Introduction

The adoption of new digital technologies, such as the Internet of Things (IoT), automation and artificial intelligence (AI), and the integration of industry 4.0 have become a priority in many organizations (Chiarini, 2020; Escobar *et al.*, 2022; Rossini *et al.*, 2023). Industry 4.0, also known

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as the fourth industrial revolution, is characterized by digitalization and the adoption of digital technologies into organizational processes. In fact, these digital technologies become interconnected through a process of digitalization – a process wherein digital techniques are connected in a social context to render a broader digital infrastructure (Tilson *et al.*, 2010; Brennen and Kreiss, 2016). This application of digital technologies – artefacts with information processing capabilities (Nolan, 1973; Tilson *et al.*, 2010), has gained traction in quality management (QM), including lean and Six Sigma, because of the advantages in organizational processes (Chiarini, 2020; Moktadir *et al.*, 2018; Rossini *et al.*, 2023).

Despite the many advantages of industry 4.0, not all organizations are suitable and capable of adopting and implementing digital technologies. Recent research suggests that organizations fail to integrate industry 4.0 because they lack dynamic and flexible strategies (Zhou *et al.*, 2016; Gunasekaran *et al.*, 2019). The implementation of digital technologies often requires different stakeholders from inside and outside the organization (March, 1991; Day, 2011) – that is, because digital technologies often affect the entire organization and also often several external stakeholders, such as customers and suppliers (Brennen and Kreiss, 2016; Elg *et al.*, 2021). Management scholars argue that the collaboration with stakeholders from inside (e.g. employees and managers) and outside (e.g. customers and suppliers) the organization is reflected in both inside-out and outside-in strategies (e.g. Baden-Fuller, 1995; Day, 2011). According to Smith and Lewis (2011), these two strategies are paradoxical – being both complementary and contradictory, highlighting the complex interplay between internal capabilities and external market forces in strategic management. In both inside-out and outside-in strategies, collaborating with internal and external stakeholders can complicate the integration of industry 4.0, as stakeholders may have divergent goals and purposes (Deleryd and Fundin, 2020). In fact, different purposes among multiple stakeholders create tensions that, in the worst case, prevent the implementation of industry 4.0.

Industry 4.0 technologies, such as the IoT, automation and AI, are diffused across various sectors, each with its own specific contextual conditions. One sector that has undergone the implementation of industry 4.0 technologies is health-care organizations, which sometimes use the denotation of Healthcare 4.0. Health-care organizations have witnessed a problem wherein different stakeholders strive for a common purpose and handle tensions, indicating it as a valuable case for examining the integration of industry 4.0. Given the challenges related to establishing a dynamic and flexible strategy for the integration of industry 4.0 within health care among multiple stakeholders, two research questions (RQs) have been formulated:

RQ1. What paradoxical tensions arise for health-care organizations when integrating industry 4.0?

RQ2. How can a paradox lens support the conceptualization and handling of tensions during the integration of industry 4.0?

A paradoxical tension can be described as two "contradictory yet interrelated elements that exist simultaneously and persist over time" (Smith and Lewis, 2011, p. 382). This paper helps clarify tensions during the integration of industry 4.0 by proposing a generic conceptual model involving both inside-out and outside-in strategies. The aim is to contribute to QM research on industry 4.0 by introducing paradox theory. While Quality Management (QM) scholars frequently propose extensions of QM (e.g. societal focus, quality 4.0 and society 5.0) by suggesting new principles, practices or specific methods (such as process stability and process management), there is an underlying assumption that one set of practices, principles and methods is superior and better than others. This paper

contributes to this discussion by emphasizing that there are no one-size-fits-all solutions for organizations when implementing different digital technologies. A paradox perspective is arguably important for managerial decision-making, for lifting QM to a more strategic level (Fundin *et al.*, 2020; Deleryd and Fundin, 2020) and for understanding how organizations can successfully integrate industry 4.0 into organizational processes (Zhou *et al.*, 2016; Gunasekaran *et al.*, 2019).

To gain detailed insights about the paradoxical tensions during the integration of industry 4.0, this paper presents a qualitative and in-depth study with a rich data set of 32 semi-structured interviews. For this special issue focusing on "Operational Excellence and Quality Improvement in Sweden", this paper describes how two health-care organizations, together with other external stakeholders, such as technology providers, patients and non-governmental health-care associations, work together to integrate industry 4.0.

The paper is structured as follows: In Section 2, a conceptual overview of the role of industry 4.0 within QM is presented, followed by inside-out and outside-in strategies, and lastly, paradox theory. Section 3 describes the methodology, and Section 4 presents the results and responds to research question one (*RQ1*). In Section 5, the paradox theory-informed conceptualization and managerial implications for handling paradoxical tensions are proposed – which are related to research question two (*RQ2*). Last, theoretical contributions to QM, conclusions, limitations and avenues for future research are proposed.

2. Conceptual background

2.1 Quality management and the strategy to integrate industry 4.0

The concept of QM is a systematic approach to management characterized by a set of practices, techniques and principles that aim to meet the expectations and needs of internal and external stakeholders through quality (Dean and Bowen, 1994; Deleryd and Fundin, 2020). Central to QM is the continuous improvement of organizational process, which may include the integration of industry 4.0. The integration industry 4.0 promises several quality improvements in terms of more dynamic and intelligent processes which enable automatic data collection, cost reductions and personalized products and services (Chiarini, 2020). Similarly, concepts like "technological advancement" (Ruben *et al.*, 2020), "digital transformation" (Alieva and Powell, 2023) and "digitization" (Clancy *et al.*, 2022) all build on the same premise as industry 4.0: digital technologies are invented, integrated and connected in a broader digital infrastructure by and for the benefit of various stakeholders (Brynjolfsson, 1993; Brennen and Kreiss, 2016). Originally, the notion of industry 4.0 has arisen in the manufacturing industry, yet this conceptualization has evolved over the past few years. Industry 4.0 nowadays does not only relate to manufacturing quality; it acknowledges a digital transformation of the entirety of societies, from the advent of smart manufacturing to digitization of entire service delivery channels (Park *et al.*, 2017). To facilitate the understandability of industry 4.0 concept, prior management scholars tend to describe this phenomenon based on technology trends and its underlying implementation principles. Technology trends acknowledge the advanced digital technological innovations such as machine learning, IoT, cloud computing, social media, big data analysis and robotics, within a broader society (e.g. Moktadir *et al.*, 2018; Chiarini, 2020). Implementation principles, on the other hand, emphasize on strategies, the progress and evolution of technologies and "know-how" knowledge during its integration into organizational processes (e.g. Castro Fettermann *et al.*, 2018; Pozzi *et al.*, 2023). A strategy refers to a course of action of how an organization competes and positions itself in its environment (Barney, 1991).

Throughout the years, several strategies how to implement digital technologies have been proposed. Several years ago, Nolan (1973), for example, proposed initiation (i.e. acquisition of digital technology), contagion (i.e. system development and connecting digital

technologies), control (i.e. managerial control of information processing capabilities and priorities for future development) and ongoing evaluation (i.e. evaluation of goal attainment and cost/benefit analysis). To date, such strategies for implementing technologies have evolved as digital technologies are affecting all aspects of organizations (Brennen and Kreiss, 2016) and often also external stakeholders, such as suppliers and customers (Elg *et al.*, 2021). In fact, recent studies suggest that some organizations fail to integrate industry 4.0 because of a lack of a strategic plan which supports the adoption of digital technologies (e.g. Zhou *et al.*, 2016; Moktadir *et al.*, 2018; Castro Fettermann *et al.*, 2018). Within QM, Gunasekaran *et al.* (2019) specifically call for more research on strategies that support continuous improvement in the era of industry 4.0. Similarly, Deleryd and Fundin (2020) suggest focussing on the strategic level of QM by considering the deployment and planning of quality initiatives that benefit society at large. Barney (1991, p. 99) suggested that any organizational strategy should seek to "exploit their internal strengths, through responding to environmental opportunities, while neutralizing external threats and avoiding internal weaknesses". This paper builds on this idea that any organization should consider both internal and external stakeholders, their capabilities and resources within the environment in the development of their strategy during the integration of industry 4.0. Formulated differently, organizations should take on both inside-out (i.e. internal focus) and outside-in (i.e. external focus) strategies.

2.2 Inside-out and outside-in strategies

The inside-out orientation is a strategic approach to management that focuses on how organizations achieve quality and operational excellence by exploiting its internal stakeholders, resources and capabilities (March, 1991; Day, 2011). In fact, it assumes organizations use their internal resources, such as specialized knowledge and skills, to take advantage of opportunities in the external environment (Barney, 1991). As an illustration, the dynamic capability approach represents an evolved form of the inside-out orientation, emphasizing the critical need for adaptation, innovation and responsiveness to changes in the external environment (Teece, 2009). Taking an inside-out perspective, organizations and its internal stakeholders, such as managers and employees, play the central role in implementing and adopting digital technologies. The literature streams of the inside-out strategy and QM suggest several capabilities which strengthen the implementation of digital technologies. These capabilities include, for example, formulating an innovation strategy (Witell *et al.*, 2011), top management support, employee training, education, resource allocation (e.g. how much and how to invest in research and development) and process design (Barley, 1991; Pozzi *et al.*, 2023). Moreover, leadership is often acknowledged as an important factor for aligning the quality culture with the type of digital technology and for coordinating knowledge exchange within organizations (Park *et al.*, 2017; Martin *et al.*, 2021).

The outside-in orientation is a strategic approach focusing on how organizations achieve quality and operational excellence by exploring external stakeholders, resources and capabilities from the environment (Day, 2011; March, 1991). Unlike the inside-out orientation, which focuses on the internal resources of the organization (Teece, 2009), this perspective focuses on acquiring knowledge about stakeholder needs and about competitors' capabilities and strategies (e.g. Sandberg, 2017; Kabel *et al.*, 2021). An outside-in orientation strongly emphasizes on value created by external stakeholders, the market position, existing technologies from competitors and active collaboration with external stakeholders (e.g. suppliers, society and government) (Day, 1994). Several studies report that there is evidence that outside-in leads to better invention and the implementation of digital technologies (Witell *et al.*, 2011) – that is, because organizations invest more resources, in

terms of time, effort and financial capital, in understanding stakeholders needs and changes in the market and society at large (Kabel *et al.*, 2020). When doing so, organizations can respond quickly and accurately to market and societal changes and offer market-relevant technologies (Teece, 2009). The literature streams of the outside-in strategy and QM suggest several capabilities for the implementation of digital technology (Lakhal *et al.*, 2006). These capabilities include customer focus, quality assurance, strategic planning, supplier quality and customer relationship management, which include the consideration of the broader system (Pozzi *et al.*, 2023; Elg *et al.*, 2021).

Because outside-in and inside-out strategies have different benefits and weaknesses, organizations generally use a balanced approach (Baden-Fuller, 1995; Day, 2011). An outside-in strategy, for example, benefits from customer, market and societal insights, but its weaknesses are related to the significant cost, time and efforts invested in sustaining the process of sensing and responding to the external environment. The inside-out strategy benefits from reduced cost, improved quality and the differentiation of market offerings (e.g. technology, information and services) through its continuous self-improvement, but its weaknesses are related to limitations in its vision and adaptability. The balanced approach between the inside-out and outside-in strategies can be studied in the light of paradox theory.

2.3 Paradox theory

Paradox theory, as proposed by Smith and Lewis (2011), aims to understand and explain the inherent tensions and contradictions that coexist within organizations. These may include, but are not limited to, the inside-out and outside-in strategy during the integration of industry 4.0. A paradoxical tension – described earlier as two "contradictory yet interrelated elements that exist simultaneously and persist over time" (Smith and Lewis, 2011, p. 382) – is characterized by three factors. First, the two elements of the paradox are:

(1) *Opposite* – that is, they appear to be illogical and irrational when combined, but make sense when considered separately;

(2) *Interdependent* – that is, they are connected and depend on each other; they are like two sides of the same coin; and lastly

(3) *Persistent* – the two elements of the paradox cannot be easily resolved or eliminated; they last for a long time (Lewis, 2000; Smith and Lewis, 2011).

For example, in QM, one paradoxical tension could be between standardization and flexibility in process operations (e.g. Fundin *et al.*, 2017). In this example, the two elements (i.e. standardization and flexibility) are opposing as they reflect contrasting, but complementary, strategies in managing process operations. The two elements are independent, with unique benefits and weaknesses. Highly standardized processes suffer from handling changing stakeholder demands and evolving stakeholder needs, while flexible processes, on the other hand, suffer from not being able to upscale production, keep costs down and create internal quality. Standardization and flexibility will always sustain and be persistent over time, where one element (standardization or flexibility) will not dominate or be superior to the other. Thus, paradox theory rejects all forms of 'one-element-fits-all' approaches and embraces organizational dilemmas which have no solution (Smith and Lewis, 2011; Schad *et al.*, 2016). Throughout the years, management scholars using paradox have studied several different paradoxes; alignment and flexibility (Smith and Tushman, 2005), stability and change (Fundin *et al.*, 2017), individual and collective (Harrison and Corley, 2011), exploration and exploitation (March, 1991; Day, 2011),

responsive and proactive (Witell *et al.*, 2011) and profit and purpose (Smith *et al.*, 2013) to name a few examples. As such studies move the management field forward, it is lagging behind as new digital technologies are invented and diffused, creating new paradoxical tensions. One influential work on how to resolve paradoxes is proposed by Adler *et al.* (1999), suggesting that organizations should introduce meta-routines, enrichment, switching and partitioning. Meta-routines refer to having "routines for changing other routines" (p. 43) and establishing standardized procedures for changing inside-out and outside-in approaches. In other words, it is about standardizing non-routine activities, such as, for example, problem-solving, experimentation and self-reflection. One meta-routine is, for example, the DMAIC methodology (e.g. Escobar *et al.*, 2022), where the problem-solving process, which is often viewed as a non-routine activity, becomes a standardized activity (through the define, measure, analyse, improve and control process). Enrichment refers to progressively adding outside-in approaches to inside-out approaches (or vice versa). This approach is especially useful for organizations that rely heavily on either an inside-out or outside-in strategy. Switching refers to introducing separate times for applying outside-in and inside-out approaches. Partitioning refers to creating departments (e.g. production and R&D) or teams within the organization that specialize in one (or both) element of the paradox for both outside-in and inside-out approaches.

To conclude, in this study, the starting point is that a balance between an inside-out and outside-in orientation is well-suited for facilitating the integration of industry 4.0. Based on this premise, this study seeks to explore the specific paradoxical tensions within both strategies during the adoption process of digital technology and go beyond the generic inside-out and outside-in orientation. Once paradoxical tensions are identified, specific approaches for handling tensions are proposed.

3. Method

Because studies of the paradoxical tensions during the integration of industry 4.0 are still scarce, a qualitative case study approach was deployed (Yin, 2018). To enhance the robustness of the paper's theoretical and empirical contributions, this study conducted an in-depth exploration (Creswell, 2007) within a multi-stakeholder research setting where different digital technologies are implemented.

3.1 Case selections and research setting

The paper presents a case context situated within two large health-care organizations located in Sweden that are implementing various digital technologies. These two health-care organizations were in the process of implementing various digital technologies, including self-monitoring, IoT platforms and advanced sensing technologies. Like many other industries, the health-care industry has witnessed a change in patient demand from an emphasis on physical encounters in clinics and hospitals to digital services enabled by various digital technologies. These digital technologies offer new possibilities for patient empowerment, personalized treatment and enhanced health-care efficiency.

For the studied health-care organizations to develop and implement digital technologies, they invited several external stakeholders, including patients, AI health, IoT platform, research institutes, professional associations, pharmaceutical providers and health funding bodies. Specifically, the two studied health-care organizations did not have the appropriate skills and knowledge alone to develop and implement digital technologies. Consequently, the integration of industry 4.0 included several external stakeholders. This multi-stakeholder research setting was deemed appropriate for studying paradoxical tensions during the integration of industry 4.0. The empirical exploration of both internal and

external stakeholders, encompassing stakeholders within and outside the health-care organizations, enabled the identification of outside-in and inside-out elements. The selection of two health-care organizations also supported in-depth case comparisons (Miles and Huberman, 1994). A Swedish context was chosen, in particular, as the specific geographical context due to its characterization by internationalization as well as early and high degrees of digital innovation (e.g. Martin *et al.*, 2021).

3.2 Data collection

In-depth interviews are particularly effective when multiple different stakeholders are interviewed (Lindgreen *et al.*, 2021). In total, 32 in-depth interviews were conducted, including with various internal and external stakeholders. More specifically, 15 interviews were conducted with internal stakeholders within the two health-care organizations, and included nurses, health-care managers, information technology managers, health-care improvement specialists, project managers and hospital coordinators – all relevant for the implementation of digital technologies. The 17 remaining interviews were conducted with external stakeholders and included marketing, customer success, business relationship, portfolio, product and brand managers, technology and app developers and pharmaceutical providers. The main sampling criterion for selecting stakeholders was, first, having experience with new digital technologies (in terms of development, implementation or use), and second, having an equal distribution of both internal and external stakeholders. Because different stakeholders were interviewed, three distinct interview guides were employed, each containing 5–10 questions. Depending on the stakeholders' roles, a specific guide was chosen. In essence, each specific guide focused on the specific activities during the development, implementation or use of digital technologies and the associated challenges. Probing questions were adapted based on the stakeholders' responses, evolving the semi-structured interview guides during the process. Data collection concluded upon reaching a point of saturation, indicating no new relevant data emerged in alignment with the two formulated research questions (Creswell, 2007). In conducting the research, this study adhered to standard ethical procedures to ensure the integrity and ethical soundness. This commitment involved obtaining informed consent from all respondents, guaranteeing their anonymity and confidentiality throughout the study. The authors ensured that respondents were fully aware of the study's purpose, their role in it and their right to withdraw at any time without any consequences. Ethical considerations extended to the careful handling and storage of data, protecting the privacy and sensitive information of the respondents.

3.3 Data analysis

The data analysis followed established qualitative coding guidelines (Creswell, 2007). To organize and compare the codes across the two health-care organizations, Nvivo 12 software was used. In total, two systematic coding cycles were used: first, using initial coding (also referred to as open coding), and second, using focused coding. In the initial coding phase, the qualitative interview data was deconstructed into first-order codes. Each first-order code reflects different activities along the development, implementation and usage process of digital technologies. During the initial coding phase, it was observed that the first-order codes harmonized well with paradox theory, indicating that the problems described were related to paradoxical tensions. In the second coding cycle, referring to focused coding, the first-order codes were categorized into overarching, second-order themes, reflecting six paradoxes and 12 elements. These 12 second-order themes or elements occurred in both health-care organizations – suggesting that the identified paradoxes were experienced across the two health-care organizations. Focused coding can be described as the process of systematic combining (Dubois and Gadde, 2002), wherein first-order codes were grouped

into elements and paradoxes – guided by the continuous interplay between empirical data and prior literature on paradoxes and industry 4.0. Importantly, systematic combining is a process that is open for the identification of new paradoxes. Formulated differently, in the second coding cycle, empirical data was linked with paradox theory (Smith and Lewis, 2011) and various outside-in and inside-out strategies (Day, 2011). The authors of this work were involved in the entire coding process to ensure that all paradoxes were identified in the empirical data. The next section of this paper directs the focus towards presenting the findings, the six paradoxical tensions and the 12 elements.

4. Findings

The study identified six specific paradoxical tensions that emerged during the integration of industry 4.0 within health care. This section corresponds to the first research question (*RQ1*): *what paradoxical tensions arise for health-care organizations when integrating industry 4.0?* As shown in Table 1, the identified paradoxes revolved around technology invention, technology collaboration (i.e. usage), technology-driven patient experience, technology uncertainty, technology invention and diffusion and technological innovation. Each paradox was represented by dual elements that the health-care organizations aimed to balance. In the following sections, the six paradoxes are described, offering insights into each element of the paradoxical tension. This exploration not only enhances the understanding of the implementation of digital technologies but also provides strategic insights for organizations dealing with these paradoxical challenges.

4.1 Technology invention: modularized or flexible design?

The paradox of technology invention refers to how health-care organizations navigate tensions during the invention of digital technology. This paradox revolves around the dual elements of adopting a modularized design or a flexible design approach to invention. During modularized design, organizations construct technology by combining smaller, standardized and interchangeable modules. Technology providers and health-care organizations emphasized the need for a set of standardized modules, including standardized questions (scales), login features and modules for data registration, to successfully scale up technology. Furthermore, it was mentioned that such technical modules are designed based on patients' self-interest (e.g. fitness and food tracking) and different patient groups or segments, each representing a specific health condition (e.g. diabetes, cancer and Alzheimer's). A project manager for self-monitoring technology at a hospital described a standardized module in terms of standardized questions (or scales) as follows:

> In the mobile app, there is a template with standardized questions that we ask about. It is not about which patient the caregiver encounters; there is a specific way this should be asked. It's like every patient receives a standardized treatment. One has the opportunity to express oneself regarding these parameters that have been determined to be relevant. Project manager

During flexible design, health-care organizations invent technology with adaptable, highly customizable features that depend on patients' abilities, needs and preferences. Despite the advantages of standardized modules in terms of upscaling and cost reduction, technology providers acknowledge that not all technological features or modules can be standardized. This is because each patient is unique, with different characteristics such as age, health condition, interests, knowledge and abilities, and they receive various cognitive and social support from their relatives (e.g. families and friends). The diverse characteristics of patients drive the need for flexible design, as well as the involvement of multiple external stakeholders, including IoT, AI health and pharmaceutical providers and other clinics and

Technology paradox	Inside-out strategy		Outside-in strategy	
	Element	Description	Element	Description
Technology invention	Modularized design	Modularized technology is a design approach in which technology is constructed by combining smaller, standardized and interchangeable modules	Flexible design	Flexible technology is a design approach in which technology is constructed with adaptable, highly customizable features or attributes depending on customers' needs and preferences
Technology collaboration	Automation	Automation occurs when organizations use technology to perform data collection tasks, where the data comes from patients and the tasks are performed without human intervention	Human augmentation	Human augmentation occurs when technology augments (cognitively and physically) the organization and patient and when the patient or organization interferes with the process of automated data collection
Technology-driven patient experience	Organization controls the patient experience	Control occurs when organizations take command and physically monitor service processes and activities where patients are participatory	Organization empowers experiences of autonomy	Autonomy occurs when organizations empower the independence and autonomy of patients through offering digital and self-service technologies
Technology uncertainty	Short-term experimentation	Short-term experimentation occurs when organizations conduct focused experiments with different technological features within a limited timeframe until an optimal solution is found	Long-term planning	Long-term planning is the process in which organizations set goals, economic and quality targets, define strategies and design a roadmap for technology invention, use and diffusion
Technology invention and diffusion through collaborative efforts among stakeholders	Selective collaboration	Selective collaboration is a careful process where the organization strategically selects specific stakeholders to collaborate with, often at various stages during technology invention and diffusion	Intensive collaboration	Intensive collaboration refers to the organization collaborating intensively with multiple stakeholders, including patients, suppliers, governments and society, often at multiple stages during technology invention and diffusion
Technological innovation	Market maintenance	Market maintenance refers to the organization adhering to and complying with local and national norms and rules associated with technology use	Market disruption	Market disruption refers to organizations' attempts to influence and shape local and national norms and rules associated with technology use

Source: Authors' own creation

Table 1.
Six technology paradoxes, with elements for the inside-out and outside-in strategy during the integration of industry 4.0

hospitals, all of which require technology with flexible design capabilities. One technology provider described flexible design as follows:

> We asked the regions [Hospital], what do you want to do? What do you want to accomplish here? Here's your toolbox. [. . .] If there's something incredibly specific that you need, some entirely new

> technology you want to test, then we need a bit more time because we might need to develop an integration, and then we configure it for you as well. If you want to change how it looks a bit, different interfaces, a different logo on the front that says whatever it is. For example, the rehab team wants to use something else, then we modify it. Technology provider

4.2 Technology collaboration: automation or human augmentation?

The paradox of technology collaboration reflects the dynamic interaction between the health-care organization and patients during technology use and data collection. This paradox centres on the dual elements of automating data collection and data exploitation or embracing human augmentation, where the organization and patients collaborate closely to customize data collection (i.e. data exploration). In this study, automation involves the process where technology performs data collection tasks without human intervention. Health-care professionals highlighted that self-monitoring technologies and automatic data collection solutions can generate substantial data sets, providing clinical insights into patients' current and future health conditions, thereby often improving their well-being. A representative from a professional health-care association described the use and benefits of automation as follows:

> Automation with notifications is crucial for development. It doesn't necessarily involve a person actively monitoring your well-being daily, but rather, there is an agreement between the patient and healthcare provider on how data should be collected. Currently, it often involves a technical sensor of some kind with a digital connection to an app. Through the app, additional data values can be manually registered, which cannot be automatically recorded. Healthcare association

In this study, human augmentation refers to the process where technology provides cognitive and physical support to both the health-care organization and the patient, and where either party actively engages with the technology to modify its data collection tasks. Health-care providers and patients explained that they sometimes need to intervene in the automated data collection process and adjust the settings on self-monitoring devices. This occurs when patients or health-care providers wish to customize and explore different settings, reflecting varying questions (from either the health-care organization or patient). Essentially, unsupervised automation or non-human operations alone are not feasible, as automation always necessitates supervision and human intervention. Both health-care providers and patients emphasized that digital technology offers them new physical and cognitive capabilities, such as understanding how medication affects their bodies or health and saving physical effort by avoiding trips to the hospital. A technology provider described human augmentation and cognitive support from technology, including human intervention, as follows:

> I [as a patient, can] input every morning and evening, how much medication I took and why. [. . .] then we receive some assistance from some form of decision support in digital form with its learning algorithm that still says, "Well, now we've found your pattern, your illness." I think it's about putting all of this together, but I believe that most patients want to get well or better. Technology provider

4.3 Technology-driven patient experiences: control or autonomy?

The paradox of patient experience refers to how the health-care organization oversees and manages the patient experience throughout the service process. This paradox revolves around the dual elements of exerting strict control over patient experiences, often through face-to-face interactions, or fostering feelings of autonomy by abandoning organizational control and encouraging patients to use self-service technologies more intensively. Instances of organizational control over patient experiences arise when organizations seek to direct and manage the patient journey. This control was evident when organizations actively monitor

service processes in which patients are actively involved. Health-care providers emphasized that patients still require a certain level of organizational support when using digital technology, as they cannot manage entirely on their own. Essentially, despite the availability of self-monitoring technology for use in patients' homes, patients still need to physically visit clinics or hospitals, even if this may not align with their preferences. A technology provider highlighted how a specific hospital was unwilling to loosen its control over patients' experiences:

> [a hospital] chose this 'control tower' approach where they initially placed no focus on outside operations [patients] and then it sorts of, nothing happened. What should I say, they were not embraced by the operations [. . .] they could not release control of their patients. Technology provider

Patients experiences of autonomy arise when health-care organizations foster patients' independence and freedom by providing self-monitoring and self-service technologies. Health-care providers emphasized that self-monitoring technologies offer patients a sense of autonomy and independence in managing their health. Nearly all stakeholders agreed that enhancing patients' autonomy was a key motivation behind the development of self-monitoring technologies. However, according to technology providers, a prerequisite for the successful implementation of self-monitoring technology is for health-care providers to trust patients and their self-reported measures, thereby loosening control. A technology provider elaborated on patient experiences of autonomy in the following manner:

> Technology provides freedom for patients or individuals with chronic illnesses, allowing you to live your life as healthy and independently as possible with the support of healthcare either alongside or remotely. This means you don't have to physically go to the hospital [. . .] Instead, you can receive the necessary support in your daily life, whether you're at work, out in the city, or at home in bed. This creates a sense of security, transforming healthcare into more of a service rather than being tied to a specific physical location. Technology provider

4.4 Technology uncertainty: short-term experimentation or long-term planning?

The paradox of technology uncertainty refers to how health-care organizations navigate uncertainty during technology invention and diffusion. This paradox involves the dual elements of engaging in short-term experimentation or planning for long-term technology diffusion. Short-term experimentation entails health-care organizations conducting focused experiments with various technological features within a limited timeframe until an optimal self-monitoring solution is reached. Many stakeholders emphasized that technology invention, use and diffusion are not fully planned, anticipated or linear processes; rather, they represent multiple journeys where multiple stakeholders experiment with their processes (i.e. manufacturing of medicine, technical configuration, routines and workflows) and existing technologies using available resources (i.e. knowledge, time and finances). Health-care organizations noted that the integration and introduction of new digital technologies need to function with existing technologies (i.e. IT systems) and processes. Hence, understanding how new digital technologies impact existing health-care processes often involves experimentation in small departments within a limited timeframe until a successful integration solution is achieved. A technology provider illustrated how health-care organizations are experimenting with new technologies within pilot projects in the following manner:

> Healthcare organizations are starting to bring in things [technology], test, and conduct pilots. Just like Kronoberg [region] did recently. Then, there is a need to discuss one's healthcare flow, the process, and re-assess it, exploring the possibility of working in a different way instead. Technology provider

Long-term planning involves health-care organizations setting goals, economic and quality targets, defining strategies and designing a roadmap for technology invention, use and diffusion. Despite the uncertainty regarding whether new technology will succeed, several health-care managers have outlined well-established goals and activities for scaling up technology. These activities include, among others, sharing patient data, presenting technological features and algorithms to other health-care organizations at conferences and on various digital platforms (i.e. websites), establishing new collaborative relationships with other health-care organizations and engaging with regulatory bodies for medical technology. The significance of long-term goals is articulated by this health-care improvement specialist as follows:

> Investing time in things that will benefit the operations is quite important. The healthcare system is under pressure, so one has to work with things that has goals and purposes which are clearly defined. Healthcare improvement specialist

4.5 Technology invention and diffusion through collaborative efforts among stakeholders: selective or intensive collaboration?

The paradox of stakeholder collaboration refers to the degree of collaboration intensity and how the health-care organization invites and coordinates with various external stakeholders (e.g. patients, technology and pharmaceutical providers) during the process of inventing and diffusing technology. This paradox revolves around the dual elements of selective and intensive collaboration. Selective collaboration is a careful process where the health-care organization strategically selects specific external stakeholders to collaborate with, often at various stages during technology invention and diffusion. Several stakeholders described that various external stakeholders, such as technology providers, pharmaceutical providers, patient and health-care associations, have different purposes and goals. A successful collaboration requires purposes and goals to be harmonized, including benefiting from data sharing (for more precise medication), writing reports and strengthening one's market brand. Importantly, the data reveals that stakeholder collaboration cannot be fully at the expense of the identity of the health-care organization, which includes organizational norms, values and beliefs. Several internal stakeholders within the health-care organizations mentioned that not all external stakeholders have to be present and involved at all stages of the process of inventing and diffusing digital technologies. One health-care improvement specialist noted that not all meetings with internal and external stakeholders were meaningful, as benefits were not equally and mutually distributed:

> [For technology providers] it's about being involved in creating reports, participating in projects, and essentially being protective of one's brand—my perception is that people want to build their brand, you know. Yes, it's nice to involve clinicians to build your brand. [. . .] Unfortunately, it has come across in that way, and it's a bit of a shame. We [as a hospital] might be considered as secondary. Healthcare improvement specialist

Intensive collaboration refers to the organization collaborating intensively with multiple external stakeholders, including patients, technology developers and professional associations, often at multiple stages during technology invention and diffusion. Certain hospital representatives described several benefits of collaborating more intensively with stakeholders inside and outside the organization, as it increases technical knowledge, improves problem-solving and strengthens relationships. One health-care improvement specialist described collaboration and working together in the following way:

> The main purpose of collaborating in the project was emphasized as wanting to do this together. However, it has become more like we do this – and then someone else does something else, and someone else does something different, and someone else does something else. Alongside being involved in this project, there's a sense that all these different actors presented in the project are doing something together. Healthcare improvement specialist

4.6 Technological innovation: market maintenance or disruption?

The paradox of technological innovation refers to how the health-care organization maintains or disrupts the market and society using digital technology. This paradox revolves around the dual elements of maintaining or disrupting (i.e. influencing) existing local and national norms and rules associated with technology usage. Specifically, market maintenance refers to the health-care organization adhering to and complying with local and national norms and rules. In other words, organizations adapt to the external environment, including norms and rules, within which they are located. Both health-care managers and technology providers described how digital technologies are designed in accordance with different national rules for digital technology, including data sharing and ownership. Moreover, digital technologies need to fit within broader societal norms. This includes the need for digital technology to meet societal expectations regarding data privacy, security, and responsible data usage, while also being seamlessly integrated into patients' daily lives. One technology provider described the importance of maintaining and complying with national rules as follows:

> With medical technology companies, there's new legislation called MDR, Medical Device Regulation, which is very costly and expensive to comply with. Companies need to have proper compliance departments, [organizational] structures, certifications, and so on. As a result, there has been a consolidation in the market, where many small companies that used to do well have either gone under or merged with others. Technology provider

Market disruption refers to organizations' attempts to influence, shape and form local and national norms and rules. Health-care managers acknowledge that they can only influence regulatory bodies, policymakers and politicians if they possess credible and legitimate evidence, such as patient data and documented improvements, proving enhanced patient well-being. Regarding norms, it was noted that digital technologies promote a shift from face-to-face encounters in hospitals and clinics to digital services in patients' homes. Moreover, some patients mentioned a shift in beliefs, recognizing that digital technologies can provide security and better decision support than nurses and doctors. One technology provider described the changing beliefs and the integration of digital technologies into patients' daily activities as follows:

> Patients need technology continuously in their daily life, whether they are at work, moving around in town, or at home in bed due to illness, there's a sense of security there where they would say that it's like; yes, healthcare becomes more of a security service rather than just a [physical] building. Technology provider

5. Discussion and implications

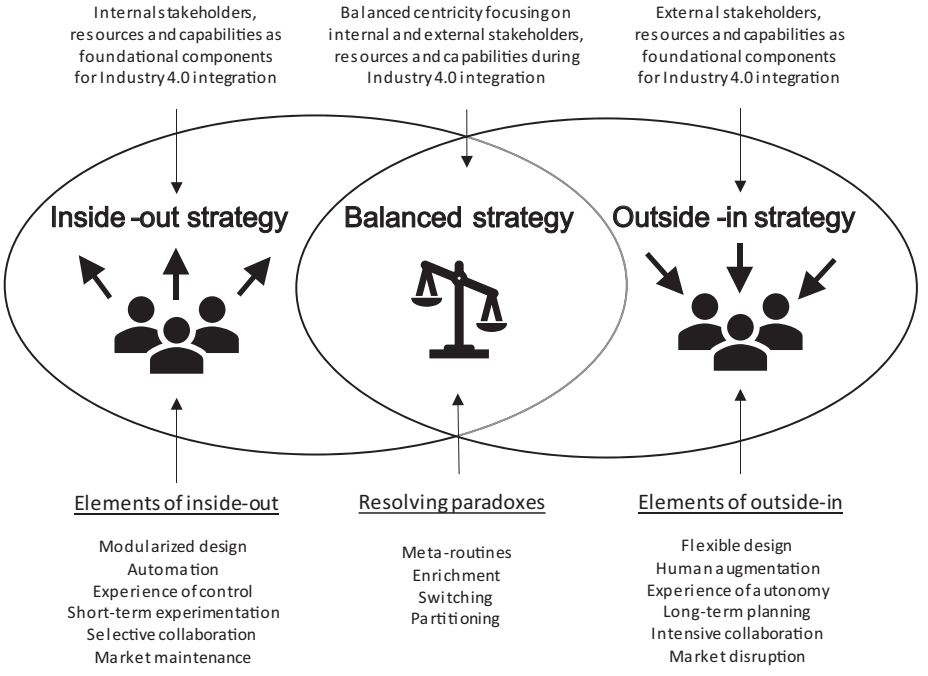
The implementation of industry 4.0 has gained traction within QM theory and among practitioners. While the implementation of industry 4.0 promises several benefits, such as improved decision-making, process efficiency and enhanced services, not all organizations are equipped to integrate it. Industry 4.0 demands a dynamic and flexible strategy and the coordination among multiple stakeholders. In this paper, the process of establishing a

flexible and dynamic strategy that involves the coordination of several stakeholders has been observed in two health-care organizations. Informed by paradox theory, the strategy for integration industry 4.0 is a balancing act that requires careful coordination among opposing and sometimes conflicting stakeholders. Organizations should not rely solely on inside-out or outside-in strategies; instead, they should combine both approaches during the integration of industry 4.0. By exploring paradoxical tensions inherent in the integration of industry 4.0 and conceptualizing techniques for managing tensions, this study contributes to the understanding of how tensions manifest in inside-out and outside-in strategies and how they can be resolved.

5.1 Paradox theory-informed conceptualization and managerial handling of tensions

This section addresses the second research question (*RQ2*): *How can a paradox lens support the conceptualization and handling of tensions during the integration of industry 4.0?* Informed by a paradox theory lens (Adler *et al.*, 1999) and depicted in Figure 1, organizations need to embrace a balancing act by implementing:

- meta-routines for both inside-out and outside-in strategies;
- enrichment of specific elements;
- strategic switching over time; and
- partitioning—wherein external stakeholders, smaller departments or business units specialize in one or both strategies.



Source: Authors' own creation

Figure 1. A paradox theory-informed conceptual model for how to handle paradoxical tension during the integration of industry 4.0

These balancing techniques for handling tensions were deemed important for establishing a dynamic and flexible strategy. These four techniques are described broadly below in relation to the findings:

(1) *Meta-routines techniques:* Establish meta-routines for periodically inviting external stakeholders and routinizing site visits with those stakeholders involved in the integration of industry 4.0. For example, the data revealed that stakeholder collaboration was deemed important – but not at the expense of the identity of the health-care organization, characterized by its norms, values and beliefs. Consequently, there was a balance between intensive and more selective collaboration;

(2) *Enrichment techniques:* Identify organizational processes that could benefit from new digital technologies while also ensuring present success in terms of patient outcomes and enrich organizational processes by updating and upgrading current technology with new digital technologies. The data revealed, for example, that health-care organizations needed to accept technological uncertainty and embrace short-term solutions and experiments to discover which organizational processes could benefit and be enriched from digital technology;

(3) *Switching techniques:* Switch between focusing on internal and external stakeholders and prioritize for how long and at what stages of the integration of industry 4.0. The data revealed, for example, that health-care organizations could either maintain their position by complying with local rules and norms or disrupt the market by improving their own position. It was evident that health-care organizations first need to gain hands-on experience of industry 4.0 and receive acceptance from their local environment. A health-care organization with hands-on experience in industry 4.0 can, in turn, switch and disrupt (i.e., influence) national rules and norms by showing evidence in terms of patient data reflecting improved patient health outcomes; and

(4) *Partitioning techniques:* Establish new roles and train employees (i.e., nurses) for industry 4.0 and start integrating industry 4.0 in small departments and teams. The data revealed, for example, that technology invention requires new sets of specialized knowledge for safely storing and analysing patient data and for configuring and connecting different digital technologies, which go beyond the knowledge of the health-care organization.

These balancing techniques to resolve tensions between the dual elements are further contextualized and detailed in Table 2. Elements associated with an inside-out strategy include modular design, automation of data collection, experience of control, short-term experimentation, selective collaboration and market maintenance. While these elements can enhance internal and objective quality and reduce the cost of technology invention, use and diffusion, they may be less adaptive to evolving stakeholder needs and changing market and societal conditions. Elements associated with an outside-in strategy include flexible design, human augmentation, experience of autonomy, long-term planning, intensive collaboration and market disruption. These outside-in elements enable organizations to adapt more readily during the continuous process of inventing and diffusing timely and market-relevant technologies, but they may involve high-cost investments.

The proposed model has the potential to offer valuable insights for managerial decision-making, especially for health-care organizations currently integrating industry 4.0. In essence, this research holds significance because existing management research and practice often underscore the common challenges associated with adopting diverse digital technologies while overlooking the underlying paradoxical tensions (e.g. Zhou *et al.*, 2016).

Technology paradox	Specific techniques for resolving paradoxes			
	Meta routines	Enrichment	Switching	Portioning
Technology invention	Create meta-routines for inviting external stakeholders, focusing on understanding what features can be standardized and what needs to be flexible	Identify potential weaknesses in terms of modularized or flexible design and strengthen the weaker element	Investigate opportunities to switch between modularized and flexible design	Collaborate with external stakeholders or create departments/ teams (e.g., R&D and in-house) that specialize in modularized and flexible design
Technology collaboration	Create meta-routines for handling spontaneous patient requests for automated data collection or human augmentation (and the process of changing automated solutions)	Identify the potential of using automated solutions and data collection features and whether it augments the organization and the patient. Strengthen the weaker element	Create collective agreements with external stakeholders on when to switch settings for automation and data collection	Create new roles for handling automation (e.g., data warehouse managers and IT specialist) and for human augmentation (e.g., nurses and doctors)
Technology-driven patient experience	Create meta-routines and workshops with external stakeholders to map the patient journey – identify variations and ensure that experiences of control and autonomy are delivered	Ensure that the health-care organization has established service processes, both physical and digital, that provide experiences of both control and autonomy	Explain the procedures to patients on how the healthcare organization will switch between physically controlled environments and digital encounters that facilitate autonomy	Create teams that seek to understand the remote and digital-enabled patient experience and teams that specialize in physical, face-to-face encounters
Technology uncertainty	Create meta-routines for conducting short-term experiments (e.g., design of experiments) and for long-term planning (e.g., creating specific, measurable, acceptable, realistic and timely goals)	Accept technological uncertainty and embrace short-term solutions and experimentation while also having a long-term plan	Switch between short-term experimentations that focus on innovative capacity and creativity and long-term planning that relies on the persistence of goals	Assign teams that specialize in focused experiments under safe conditions and teams that set and evaluate the progress in achieving organizational goals

(*continued*)

Table 2.
How health-care organizations can handle paradoxical tensions during the integration of industry 4.0

Technology paradox	Specific techniques for resolving paradoxes			
	Meta routines	Enrichment	Switching	Portioning
Technology invention and diffusion through collaborative efforts among stakeholders	Create meta-routines and stakeholder maps to ensure that relevant stakeholders are involved at appropriate stages during the invention and diffusion of technology	Identify and ensure that relevant stakeholders, with specialized knowledge, are involved in the process of inventing and diffusing technology	Engage external stakeholders that facilitate beneficial exchanges and switch between selective and intensive collaboration	Create roles that are specialized in socialization and interacting with external or internal stakeholders on physical conference and other stakeholder constellations
Technological innovation	Create meta-routines and operational processes that adhere to local and national norms and rules while also collecting data for disrupting, or at least, influencing, existing rules	Ensure that the health-care organization is both influencing the market and that the market is influencing the organization	Comply with local and national norms and rules and switch to influencing regulatory bodies and politicians if legitimate evidence is available in the health-care organization	Create roles that collect legitimate evidence and data (or information) for creating awareness in society and influencing regulatory bodies and politicians

Table 2. **Source:** Authors' own creation

From a paradox theory perspective (Smith and Lewis, 2011), this paper highlights that the integration of industry 4.0 might fail because of organizations' inability to see and resolve paradoxical tensions – which requires dynamic and flexible strategies. Consequently, quality managers are encouraged to carefully examine and understand the different paradoxes they may encounter. Given that paradoxes are typically interrelated (Smith and Lewis, 2011), organizations should not view one element (i.e. side of the paradox) as superior; instead, they should consider both elements during the integration of industry 4.0. While this paper identifies six recurring paradoxical tensions, it serves as a starting point for health-care organizations. However, further exploration may be necessary for health-care organizations to uncover more context-specific tensions.

5.2 Theoretical contributions to quality management

This paper contributes in two significant ways to QM. Firstly, it identifies and categorizes paradoxical tensions inherent in both inside-out and outside-in strategies, advocating for a more strategic role for QM. The findings underscore that the integration of industry 4.0 with multiple stakeholders requires the managerial handling of multiple tensions. QM has a critical role within health-care organizations during the integration of industry 4.0 – that is, because digital technologies impact the entirety of organizations and their external stakeholders, including patients and suppliers. For instance, the study highlights how the patient experience varies based on whether health-care organizations seek to control it or

empower autonomy through self-services and digital technology. As described by Elg *et al.* (2021), QM's role transcends mere operational functions or specific departments; it includes all organizational functions and inherently holds strategic significance as its products, services and information aim to benefit society at large. The integration of industry 4.0 with the digital infrastructure it fosters among diverse stakeholders (Brennen and Kreiss, 2016) triggers a paradigm shift wherein operational QM transitions to a more strategic role. Such insights are crucial for leadership and the formation of quality cultures. Particularly, the paper responds to the call for a "framework for leading and managing through rapid changes" (Fundin *et al.*, 2020, p. 6) by proposing a generic conceptual model inspired by paradox theory. This paper does not present a one-fit-solution, instead; organizations should identify and organize for paradoxical tensions.

Secondly, the paper provides clarity on addressing quality-related challenges and dilemmas during the integration of industry 4.0, thus guiding strategic decision-making (Deleryd and Fundin, 2020). While QM scholars often propose extensions of QM (e.g. societal focus, Quality 5.0 and Society 5.0) by advocating for new sets of principles, practices or specific methods (e.g. process stability and management), there persists an underlying assumption that certain practices, principles or methods are superior to others. This paper contributes to this discussion by emphasizing that there are no one-size-fits-all solutions for organizations; rather, multiple paradoxical elements can address organizational challenges. The role of the organization is to learn from tensions and to organize organizational process to handle tensions. QM should not discard existing principles, practices or methods; instead, QM scholars and practitioners should embrace meta-routines, enrichment, switching and partitioning strategies that do not favour specific principles, practices or methods. By exploring tensions among different stakeholders through the lens of paradox theory, QM scholars and practitioners can strategically engage in quality improvements. By bringing clarity and awareness to paradox thinking within QM research, this paper could inform strategic decision-making (Deleryd and Fundin, 2020).

6. Conclusions and future research

Inside-out and outside-in strategies offer health-care organizations with numerous advantages in resolving tensions within multi-stakeholder constellations, competitive markets and evolving stakeholder needs. For QM, new technologies hold the potential to enhance fact-based decision-making, improve process efficiency and foster cycles of continuous improvement. The rapid diffusion of digital technologies and the emergence of industry 4.0 and digitalization initiatives give rise to new paradoxical tensions within health organizations that need to be addressed. This study explored the paradoxical tensions inherent in inside-out and outside-in strategies throughout the implementation process of new digital technologies. Through a qualitative exploration involving various digital technologies, six paradoxical tensions during the integration of industry 4.0 were identified. These tensions included technology invention (modular design vs. flexible design), technology collaboration (automation vs. human augmentation), technology-driven patient experience (control vs. autonomy), technology uncertainty (short-term experimentation vs. long-term planning), technology invention and diffusion through collaborative efforts among stakeholders (selective vs. intensive collaboration) and technological innovation (market maintenance vs. disruption). Quality management can effectively navigate these paradoxes by adopting a balanced strategy that combines both outside-in and inside-out orientations. This can be achieved by introducing meta-routines for both strategies,

enriching one strategy, switching strategies over time and partitioning, where external stakeholders, smaller departments or business units specialize in one or both strategies.

This study has three limitations worth noting. Firstly, it focused on a health-care context in Sweden. Additional tensions may be uncovered by exploring other contexts (e.g. industries and geographical areas). Secondly, as a qualitative study, this paper did not examine the relative importance of each tension in relation to, for example, business performance and patient satisfaction. Future research could quantify and measure the importance of each tension and its business impact. Thirdly, this study used a paradox theory perspective as a novel lens to study the integration of industry 4.0 within the QM domain. Future research could use other theories, such as institutional or psychological theory, to further explore the integration of industry 4.0.

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Corresponding author
Daan Kabel can be contacted at: daan.kabel@liu.se