Doctoral theses at NTNU, 2022:24

Doctoral thesis

Eirik Bådsvik Hamre Korsen

Towards control or empowerment?

How performance measurement systems and performance management practices interact with digital technologies in Norwegian manufacturing organisations

NTNU
Norwegian University of Science and Technology
Thesis for the Degree of
Philosophiae Doctor
Faculty of Economics and Management
Dept. of Industrial Economics and
Technology Management

NTNU
Norwegian University of
Science and Technology

Eirik Bådsvik Hamre Korsen

Towards control or empowerment?

How performance measurement systems and performance management practices interact with digital technologies in Norwegian manufacturing organisations

Thesis for the Degree of Philosophiae Doctor

Gjøvik, February 2022

Norwegian University of Science and Technology
Faculty of Economics and Management
Dept. of Industrial Economics and Technology Management

NTNU
Norwegian University of
Science and Technology

NTNU
Norwegian University of Science and Technology

Thesis for the Degree of Philosophiae Doctor

Faculty of Economics and Management
Dept. of Industrial Economics and Technology Management

ISBN 978-82-326-5588-5 (printed ver.)
ISBN 978-82-326-6557-0 (electronic ver.)
ISSN 1503-8181 (printed ver.)
ISSN 2703-8084 (online ver.)

Doctoral theses at NTNU, 2022:24

Printed by NTNU Grafisk senter

Abstract

Performance measurement and management (PMM) systems are a central element in how organisations are managed. In manufacturing, researchers predict that "Industry 4.0" and associated digital technologies – e.g. cyber-physical systems, big data, and artificial intelligence – will radically change how work is performed and managed. However, the PMM literature does not agree on what effect the deployment of digital technologies will have on PMM systems. On one hand, the increased access to data can be used as augmented intelligence and be an enabler for empowerment. On the other hand, extensive automatisation and use of artificial intelligence can lead to a more command-and-control management style. Following this discussion, this thesis asks *how performance measurement systems and performance management practices interact with digital technologies*.

The results are based on three cases from Norwegian manufacturing organisations, and described in four articles. The data analysis is based on a combination of Smith and Bititci's (2017) framework for PMM, Bourne *et al.*'s (2018a) system of systems perspective, and Orlikowski's (1992) idea of duality of technology. By combining the three theoretical components with the empirical findings, this thesis identifies *how interaction between PMM and digital technologies occurs in sub-systems*, and *how the digital technologies are influenced by and reinforce existing management practice*. By viewing the PMM system as a collection of sub-systems that together maintain the balance between command-and-control and empowerment, this study identifies how digital technologies can be implemented and make changes to a sub-system without disturbing the overall balance of the PMM system.

One limitation of the thesis is that it is based on cases that all promote an empowering management style. Additional cases oriented toward a command-and-control setting are necessary to confirm the proposition that digital technology can reinforce any sub-systems. To extend our knowledge on how PMM evolves, this thesis argues that future PMM research should stop viewing technology as an external or contingency factor and

start asking who is using digital solutions and for what purpose, and how they create changes to the PMM system and practices.

Sammendrag

Organisasjonens virksomhetsstyringssystem er et viktig element i hvordan organisasjonen ledes og styres. Det påvirkes av og utvikles i takt med teknologiutviklingen. Organisasjonene har tilgang på en rekke digitale teknologier, f.eks. "Cyber-physical systems", "big data" og kunstig intelligens, som i vareproduserende industri blir omtalt som "industri 4.0". Enkelte antar at digitalisering igjennom industri 4.0 teknologier radikalt vil endre både hvordan vi jobber og hvordan vi utfører ledelse. Men innenfor litteraturen som diskuterer virksomhetsstyring er det usikkerhet om hvordan digitale teknologier vil påvirke virksomhetsstyringssystemet. På den ene siden kan økt tilgang på data bli brukt som utvidet intelligens (augmented intelligence), det vil si å tilgjengeliggjøring av data for å gi innsikt, understøtte og forenkle oppgaver som problemløsning og beslutningstaking, og dermed muliggjøre økt selvstyring eller myndiggjøring (empowerment). På den andre siden, kan økt automatisering og bruk av kunstig intelligens føre til mer sentralisering av beslutninger, regelstyrte systemer og en ledelsespraksis som beskrives som "command-and-control". Denne doktorgradsavhandlingen bidrar til i denne diskusjonen, og stiller spørsmål om hvordan organisasjonen virksomhetsstyringssystem og digitale teknologier samhandler.

Resultatene i avhandlingen er basert på tre case-studier fra Norsk vareproduserende industri, som er beskrevet i fire artikler. Tre teoretiske komponenter er sentrale i analysen av casene. Det er første er Smith and Bititci´s (2017) teoretiske rammeverk for virksomhetsstyring, hvor system for prestasjonsmåling og ledelsespraksis blir sett på som to dimensjoner som påvirker hverandre. System for prestasjonsmåling er de faste prosessene organisasjonen har for å sette seg mål, samle inn styringsinformasjon, analysere, rapportere og evaluere resultatene. Som regel er det en form for måltall og/eller budsjetter, kvalitetssystemer og prosess- og rutinebeskrivelser. Ledelsespraksis dimensjonen skiller mellom i hvilken grad det er sentralstyrt som betegnes som "command-and-control", eller om det er større grad av distribuert styring og involvering som betegnes som "empowerment". Den andre teorien er Bourne *et al.* (2018a) sitt perspektiv på virksomhetsstyringssystemet som et system av systemer, hvor flere sub-systemer, f.eks. budsjett, måltall og kvalitetssystemer, blir brukt parallelt og kan være

mer eller mindre tett koblet. Den tredje komponenten er Orlikowski´s (1992) ide om "teknologiens dualitet", hvor både design og utvikling av teknologi og bruken av teknologi påvirkes av erfaringer og oppfatningene til henholdsvis teknologiutviklerne og brukere. Ved å analysere data fra case-studiene i lys av de teoretiske rammene indentifiserer jeg hvordan samhandlingen mellom virksomhetsstyringssystemet og digitale teknologier skjer i sub-systemer, og hvorpå implementeringen av digitale teknologier er påvirket av og forsterker eksisterende ledelsespraksis.

Ved å se på virksomhetsstyringssystemet som en samling av sub-systemer, som samlet sett balanserer "command-and-control" og "empowerment", identifiserer studien hvordan digitale teknologier kan bli implementert i et sub-system uten at det påvirker den overordnet balansen i virksomhetsstyringssystemet. En begrensning i denne studien er at alle casene promoterer høy grad av selvstyring og "empowerment". Det er derfor behov for andre case-studier av organisasjoner som er sentralstyrt og kjennetegnet av "command-and-control" for å kunne bekrefte påstanden om at digitale teknologier vil forsterke eksisterende praksis i sub-systemer.

For å kunne videreutvikle forståelsen av hvordan virksomhetsstyringssystemer utvikler seg, argumenterer denne doktorgradsavhandlingen for at vi må endre hvordan vi studerer teknologiens påvirkning. Fra å se på teknologier som en ekstern eller betingende faktor, til å stille spørsmål om hvem som tar digitale løsninger i bruk, til hvilket formål, og hvordan det endrer virksomhetsstyringssystemet og ledelsespraksisen.

Acknowledgements

This PhD project was part of the research project “SFI Manufacturing”, and was funded by the Research Council of Norway and Norwegian manufacturing companies. SFI Manufacturing is a consortium of 15 manufacturing companies in Norway, SINTEF (a research organisation), and NTNU. Thank you, Monica Rolfsen, for opening the door to a PhD position within this research project. I am very grateful to have become part of this research consortium and been able to meet practitioners and fellow PhD students and academic colleagues. The semi-annual seminars and factory visits have been inspiring. Informal discussions have been fruitful in developing thoughts and reflection throughout the work within the PhD. Special thanks to the case-study organisations and the informants for setting aside your time and sharing your experiences and thoughts with me. Without your contribution I would not have any story to tell.

I have been on this PhD journey for more than four years. Throughout, I have had the privilege to meet and work with some outstanding people who have influenced my work in different ways, and whom I would like to acknowledge.

First and foremost, my greatest gratitude to Jonas A. Ingvaldsen, who has been my main supervisor. Without your generosity to read through endless drafts, challenging my ideas and thinking, giving me honest and constructive feedback, and contributing with your experiences and knowledge when co-writing articles, I would probably not have reached the end of this journey. You have become a colleague and friend, which I greatly appreciate. Thank you!

I would like to thank my co-supervisors: Øyvind Helgesen, for constructive conversations and feedback in the beginning of my PhD project and the work with my first academic article; and Heidi Carin Dreyer, for introducing me to your network and opening the door to the academic field of PMM.

Participating in PhD courses and academic seminars is a joyful part of the PhD journey. Thank you, instructors and fellow students for good discussions and your openness in

sharing ideas and knowledge. Special thanks to Umit S. Bititci for participating in my midterm seminar and giving me constructive feedback on my work. My fellow PhD students, Torbjørn Hekneby and Dan-Richard Knudsen, I appreciate your friendship and supportive conversations.
Collaboration with a colleague when doing research is truly much more educational and fun then traveling to rural places on my own. Thank you, Marte Daae-Qvale Holmemo, for the possibility to work with you and learn from your research experience.

I would like to thank all my colleagues at Gjøvik. I appreciate all the informal conversations with you that have provided me with the little drips of inspiration I needed during this long, and at times frustrating, journey.

Finally, my warmest gratitude goes to my family. With my wife, Anne Siri, and our children, Emil, Tiril, and Martin, together we create an ordinary and day-to-day life that provides a balance that makes a PhD project such as this possible.

Eina, August 2021
Eirik Bådsvik Hamre Korsen

Table of contents - part 1:

List of figures in part 1

List of tables in part 1

Independent articles in part 2

Part 1

1 Introduction

Performance measurement systems and performance management practices (PMM) are recognised to be central elements in organisations to achieve strategic alignment (Kaplan and Norton, 2008), coordinate activities, and continuously improve the efficiency and effectiveness of the organisation (Neely *et al.*, 1995). The PMM literature has evolved from focusing on the design of performance measurement systems (PMS) toward how measures are being used in performance management practices (Bititci *et al.*, 2016; Neely *et al.*, 1995) to balance control and empowerment (Simons, 1995b). In this context, access to and communication of data and information are critical (Garengo *et al.*, 2007b; Marchand and Raymond, 2008; Nudurupati and Bititci, 2005; Nudurupati *et al.*, 2011), and the emerging digitalisation is identified as one of the key challenges in the future development of PMM systems (Bititci *et al.*, 2012).

Currently, the manufacturing industry is facing the so-called "fourth industrial revolution" (Reyes *et al.*, 2016), where this "Industry 4.0" offers a set of digital technologies including cyber-physical systems, the internet of things, robotics, big data, cloud manufacturing, artificial intelligence, and augmented reality (Frank *et al.*, 2019; Robert *et al.*, 2020). The investments in digital technologies in 2021 are forecasted to pass 25% of the global information and communication technologies (ICT) spending of more than 5 000 billion US dollars (IDC, 2019), and predicted to lead to significant changes to organisations (Davenport and Ronanki, 2018; Fountaine *et al.*, 2019; McAfee and Brynjolfsson, 2012). Large consulting firms (Deloitte, 2021) and governmental organisations – such as the European Commission and World Economic Forum – discuss how the increase in digital technologies will radically change the nature of work and the skills of employees (Bughin *et al.*, 2018; Gonzalez *et al.*, 2019; Pardi *et al.*, 2020; Reyes *et al.*, 2016), and some fear that jobs based on information processing will be replaced by computers (Schäffer and Weber, 2019).

The adaption and deployment of digital technologies create great opportunities for improvements. Automatic and real-time data collection, analysis, and reporting enable use of more frequent and detailed performance measures (Sardi *et al.*, 2019; Sardi *et al.*, 2020a). However, the effects of digital technologies on performance management practices are still uncertain, as existing research documents diverse development (Nudurupati *et al.*, 2021; Robert *et al.*, 2020; Sardi *et al.*, 2020b; Smith and Bititci, 2017). On the one hand, transparent use of rich performance data can be an enabler for empowerment (Bititci *et al.*, 2018; Melnyk *et al.*, 2014; Nudurupati *et al.*, 2021). On the other hand, extensive automation might overengineer people management, leading to disempowerment and more command-and-control (Bailey and Barley, 2020; Cappelli, 2020). Such uncertainty and contradictory predictions and findings can be explained by the PMM research tendency to address the PMM system as a monolithic system (Bourne *et al.*, 2018a), and view technology as a contingency factor (Garengo *et al.*, 2007a) or even as an imperative to reorganise (Orlikowski, 1992). It remains a basic insight that PMM systems are complex and deal with contradictive measures (Kaplan and Norton, 2008; Melnyk *et al.*, 2014), and that organisations make choices about what purpose the technology is supposed to serve (Bailey and Barley, 2020). Still, our understanding of how these digital technologies interact with organisations' PMM systems is in its infancy (Nudurupati *et al.*, 2021; Sardi *et al.*, 2019).

This thesis aims to contribute to the discussion and advance our knowledge by asking the overall research question:

> **How do performance measurement systems and performance management practices interact with digital technologies?**

To answer this question, this thesis builds upon Smith and Bititci's (2017) theoretical framework for PMM, which views performance measurement and performance management as two separate yet interrelated dimensions. To address the complexity and diversity that exist in organisations' PMM systems (Melnyk *et al.*, 2014), Smith and Bititci's (2017) framework is expanded with a "system of systems" (SoS) perspective (Bourne *et al.*, 2018a). This perspective recognises that a PMM system in practice is a collection of sub-systems that are design and deployed in different departments within the organisation, and are loosely or tightly coupled (Demartini and Otley, 2020). To understand how digital technologies are deployed in the organisations as a result of management choices and influenced by existing practices, this thesis adapts Orlikowski's (1992) idea of the "duality of technology".

Methodologically, this thesis is based on a qualitative research design to understand the dynamics in the PMM processes and how they interact with digital technologies in design, implementation, and use (Graebner *et al.*, 2012). It rests upon three case studies conducted by the candidate in Norwegian manufacturing industries, resulting in four articles. The articles are summarised in Table 1.

Combining the three theoretical components with empirical data crystallises two important patterns. First, the **interaction between PMM and digital technologies occurs in sub-systems**. Second, since the organisations approach digitalisation through involvement of in-house employees in both design and implementation, the **digital technologies are influenced by and reinforce existing management practice.** These two finding have consequences for both theory and practice.

Addressing the PMM system as a collection of sub-systems (Bourne *et al.*, 2018a) allows us to analyse how the balance between command-and-control and empowerment is maintained within and across different sub-systems. As the sub-systems are loosely connected, this allows digital technologies to be implemented to a sub-system, increasing control or promoting empowerment without disturbing the balance of the PMM system as a whole. The extent to which the sub-systems are tightly or loosely coupled is expected to influence the complexity of digital technology deployment and the extension of its interaction with sub-systems.

Taking a duality of technology view (Orlikowski, 1992) enables us to understand how digital technologies and PMM interact in sub-systems through the activities of middle managers. As middle managers are involved in the design and implementation, they are seeking solutions which facilitate and improve work processes. Digital technologies in these cases do not replace work; rather, they are used to augment the intelligence (Bailey and Barley, 2020) of middle managers and operators in decision making and problem solving. As digital technologies are deployed in an iterative and evolutionary process, this questions the notion of an ongoing digital "revolution" (Bughin *et al.*, 2018; Gonzalez *et al.*, 2019; Pardi *et al.*, 2020; Reyes *et al.*, 2016).

Practical implications of these findings address how a sub-system approach both reduces the scope and complexity of projects implementing digital technologies, and can be targeted to promote intended management practice. In addition, by involving in-house employees in design and implementation, they become "bilingual" and understand the digital language representing their processes. This awareness means that the digital solutions do not become a "black box" for users (Davenport and Ronanki, 2018).

Table 1: Summary of the four articles that underpin this thesis

#	Title	Method	Research purpose	Contribution to the thesis
1	Digitalisation and the performance measurement and management system: reinforcing empowerment	Single case study of Alpha	Explores how ICT can contribute to empowerment in an Industry 4.0 setting.	It confirms that digital technologies mature the PMS (Sardi *et al.*, 2019). Existing management practice is reinforced, in this case toward empowerment. Alpha chose to use digital technologies as augmented intelligence to support operators and middle managers in decision-making and problem-solving tasks.
2	Digital technologies and the balance between control and empowerment in performance management	Single case study of Beta	Explores how the balance between command-and-control and empowerment in PMM systems is altered when organisations deploy digital technologies.	The PMM system is analysed as a collection of sub-systems, in line with the SoS perspective (Bourne *et al.*, 2018a). The finding from the case shows how an intervention by digital technologies to a sub-system affects only the sub-system, without disturbing the balance in the overall PMM system.

3	Balanced Scorecard and Hoshin Kanri: Why and how they might be used together	Single case study of Gamma	Explores how different PMS – balanced scorecard and Hoshin Kanri – can be combined to support strategic alignment.	Written prior to Bourne *et al.* (2018a), this introduced the SoS perspective. In retrospect, it is an illustration of how different sub-systems develop in different departments to meet specific managerial needs, and are not designed centrally as monolithic and homogenic systems that are cascaded down. The article is also a good illustration of qualitative methodology, where the process of exploring a phenomenon takes the researcher into another direction than first anticipated.
4	Digitalization studied from a performance measurement and management perspective – augmented intelligence?	Multiple case study of Alpha, Beta, and Gamma	Explores how cognitive (digital) technologies are deployed in Norwegian industry, and the associated consequences for how work is performed and managed.	To some extent, this article can be seen as the “flip side” of this thesis, as it analyses the consequences of digital technology adoption in organisations from a PMM perspective. By comparing the cases, it identifies how digital technologies are deployed to sub-systems in an iterative and involving process through design and use. As the article takes a technology approach, it introduces Orlikowski’s (1992) duality of technology to explain how technology is influenced by people both in design and use. It identifies how digital solutions reinforce exiting management practices to build upon continuous improvement where involvement and empowerment are key elements.

The remainder of the thesis is structured as follows. Continuing Part 1, the second chapter reviews relevant literature, drawing the longer historical lines of the development of the PMM filed and digital technologies before exploring three central theoretical components for this thesis. The third chapter discusses the methodology used, including its limitations. The fourth chapter summarises the four articles with key findings and theoretical contributions. The fifth chapter discuss the implications of the main finding for the PMM research. The sixth chapter addresses practical implications before offering a conclusion. The second part of this thesis presents the four articles.

2 The evolution of PMM and the introduction of digital technologies

Johnson and Kaplan's "*Relevant lost: The rise and fall of management accounting"* (1987) can be seen as the start of a new era in performance management discussion and is referenced by a majority of scholars (Bititci *et al.*, 2012). This discussion has flourished across academic disciplines, including management accounting, operation management, and human resource management, among others (Neely, 2005; Neely *et al.*, 1995). However, as a scholar studying PMM, the cross-disciplinary attention both provides enrichment and causes some frustration in the hunt to identify a theoretical framework as the foundation for this thesis. With the aim of illuminating the relevant theoretical background to discuss how Industry 4.0 and the associated digital technologies influencing PMM today, this chapter is divided into six subsections. The first subsection reviews some of the major trends in the evolution of PMM. The second subsection presents the selected theoretical framework from Smith and Bititci (2017) that this thesis builds upon. The third addresses how ICT have been essential to PMM systems and how Industry 4.0's digital technologies differ from those of Industry 3.0. In the fourth subsection, I address the ongoing discussion in the literature on how digital technologies interact with PMM, and the need to extend existing theories. The fifth subsection introduces the SoS perspective (Bourne *et al.*, 2018a) as an alternative perspective to the dominant monolithic and homogenic perspectives of PMM systems. The sixth and last subsection addresses a perspective on how organisations adopt technology, and introduces the theory of duality of technology (Orlikowski, 1992).

2.1 Evolution of PMM

In the evolution of PMM, performance data and measurements have expanded from accounting to a variety of technical and economic measures. The technologies to collect, analyse, and report performance data have been important to this development, and now we are facing a shift to Industry 4.0 and digital technologies.

2.1.1 Relevance lost

The first signs of performance measurement emerged in the double-entry bookkeeping that appeared in the late 13th century (Johnson, 1981). This remained unchanged up to the first industrial revolutions in the 19th century (Bititci *et al.*, 2012). With the establishment of industrial organisation, access to performance data became essential, both to achieve superior profits from better planning and coordination of activities (Johnson and Kaplan, 1987) and to introduce wages (Bititci *et al.*, 2012). Bookkeeping and accounting gained a vital position in the organisations, as they offered a solution to systematically collect, analyse, and report data reflecting performance. In Taylor's (1911) scientific management, cost accounting was a central element in measuring production effectiveness and in the argument on how a reduction of cost and increased wages could be combined. DuPont's accounting innovation of the return on investment formula from around 1915 enabled comparison of performance between divisions as a basis for management decisions in investments and allocation of resources (Johnson and Kaplan, 1987). The accounting position in management was reinforced by the financial market requirement for standardised audited financial information (Anthony and Reece, 1975), and the emergence of management accounting as an academic discipline with business schools educating auditors and managers (Johnson and Kaplan, 1987). In the period from around the 1930s to 1990s, budgetary control based on accounting information became a dominating performance measurement (Anthony and Reece, 1975; Bititci *et al.*, 2012). According to Johnson and Kaplan (1987), management accounting information lost its relevance in managing organisations' operational performance, as it was driven by a financial reporting system that was "too late, too aggregated, and too distorted to be relevant for managers' planning and control decisions" (p. 1). The management-accounting information focus was to maximise the organisations' financial performance toward the financial market. It did not provide detailed information on process efficiency or reflect accurate production costs. Such focus on short-term profit can compromise long-term goals.

2.1.2 Parallel development across multiple fields

Johnson and Kaplan (1987) describe management accounting foremost from an American perspective. From an operational or engineering perspective, approaches based on the scientific management tradition had continued to develop both in American industries and in other countries (Evans and Evans, 2011). In France, the engineer association developed a "tableau de bord" in the 1930s (Lebas, 1994), a PMS similar to what many today associate with the "balanced scorecard" (Bourguignon *et al.*, 2004). During the 1950s, more advanced methods for productivity management developed, including quality control or total quality management, and just-in-time production (Bayraktar *et al.*, 2007; Bititci *et al.*, 2012; Krajewski *et al.*, 2016; Womack *et al.*, 1990). However, in a time when the supply side was driving the economy, the improvements in productivity were measured by financial indicators at the expense of customer and employee satisfaction (Johnson and Kaplan, 1987; Kaplan, 1983; Neely *et al.*, 1995). With the shift in the economy between the 1960s and 1980s – toward the demand side – new dimensions of measuring performance gained importance, including quality, time, flexibility, and customer satisfaction (Bititci *et al.*, 2012; Johnson and Kaplan, 1987; Kaplan, 1984). In addition, as globalisation gained momentum, international competitiveness revealed differences in productivity, and the attention on how to manage operations received a boost as practitioners and academics in the US looked to Japan and their "lean production" model (Johnson and Kaplan, 1987; Womack *et al.*, 1990). Together, these changes acknowledge performance measures as a multidimensional domain (Johnson and Kaplan, 1987; Neely *et al.*, 1995), with the following development of more integrated and balanced frameworks and models for PMM (Bititci *et al.*, 2012; Cooper and Kaplan, 1991; Kaplan and Norton, 1992).

2.1.3 Relevance regained as a multidisciplinary field

Following the "relevance lost" (Johnson and Kaplan, 1987) debate, several innovating management tools were introduced (Ravelomanantsoa *et al.*, 2018), including activity-based costing (ABC) (Atkinson, 2012; Cooper and Kaplan, 1991), levers of control (Simons, 1994), the performance pyramid (Cross and Lynch, 1989), the integrated performance measurement system (Bititci *et al.*, 1997), and the balanced scorecard

(Kaplan and Norton, 1992, 1993) as the most cited (Neely, 2005; Neely *et al.*, 1995; Taticchi *et al.*, 2012). These frameworks were in common holistic and integrated (Bititci *et al.*, 2012), and their dominant focus was on what to measure (Kaplan and Norton, 1993; 1996; Neely *et al.*, 1995), and how to design and implement PMS (Bourne *et al.*, 2003) to achieve strategic alignment (Bititci *et al.*, 1997). This discussion developed across different disciplines, including strategic management, information management, and human relations, in addition to management accounting and operation management (Bititci, 2015; Bititci *et al.*, 2018; Neely, 2005; Neely *et al.*, 1995; Taticchi *et al.*, 2012).

Following this innovative and multidisciplinary development, there were three dilemmas worth mentioning. First, the new models with a more balanced and/or detailed view of the organisations' performance require increased access to and processing of data, where at the time the ICT still consisted of single-purpose applications, and the integration of data was either too expensive or required extensive work. For example, one reason for ABC not diffusing was the extensive data processing required to associate costs to single activities (Atkinson, 2012). Section 2.3 outlines the ICT development and PMM in more detail. Second, PMS was viewed as a monolithic system (Bourne *et al.*, 2018a; Malmi and Brown, 2008), not recognising that different systems are introduced in different departments within an organisation. See section 2.4 for more details on how an SoS view (Bourne *et al.*, 2018a) addresses this dilemma. Third, the multidisciplinary development resulted in different academic disciplines developing parallel theories and models with different terminology for similar definitions or concepts. For illustration purposes, Table 2 summarises some the terminology used in management accounting versus operation management. Note, this thesis associates itself with operation management and the according PMM terminology.

Table 2: Illustration of taxonomy used in management accounting versus PMM

Management accounting terminology		
Expression	**Definition**	**Source**
Accounting	“Accounting is the art of recording, classifying, and summarizing in a significant manner and in terms of money, transactions and events which are, in par at least, of financial character, and interpreting the results thereof.”	Anthony and Reece (1975, p. 7)
Management accounting	The accounting information specifically intended for carry out management responsibilities, categorised as control, coordination, and planning.	Anthony and Reece (1975, p. 5)
Financial accounting	“Accounting information is intended both for managers and, including shareholders, bankers and other creditors, government agencies and the general public.”	Anthony and Reece (1975, p. 6)
Management accounting system	Refers to the systematic use of management accounting to achieve some goals.	Chenhall (2003, p. 129)
Management control	“[t]he process by which managers assure that resources are obtained and used effectively and efficiently in the accomplishment of the organization’s objectives.”	Anthony (1965) referred to in Langfield-Smith (1997, p 208), and Johnson and Kaplan (1987, p 168), among others.
Management control system (MCS)	“[a] set of many formal and informal input, process and output controls that are used by management to achieve organizational goals.”	Chenhall and Moers (2015, p. 1)
Operational control	“[t]he process of assuring that specific tasks are carried out effectively and efficiently.”	Anthony (1965) referred to in Johnson and Kaplan (1987, p. 168)
Performance management system	“[t]he evolving formal and informal mechanisms, processes, systems, and networks used by organizations for conveying the key objectives and goals elicited by management, for assisting the strategic process and ongoing management through analysis, planning, measurement, control, rewarding, and broadly managing performance, and for supporting and facilitating organizational learning and change.”	Ferreira and Otley (2009, p. 264)

MCS as package	A collection of a set of controls and control systems, as in most organisations there are a number of MCS.	Malmi and Brown (2008)
Operation and technology management terminology		
Performance	Efficiency and/or effectiveness of an action	Bititci *et al.* (2018, p. 655)
Performance measures	"[a] matric used to quantify the efficiency and/or effectiveness of an action."	Neely *et al.* (1995) referred to in Melnyk *et al.* (2014, p. 175), and Bititci *et al.* (2018, p. 655), among others.
Performance measurement system	"[t]he process (or processes) of setting goals, developing a set of performance measures, collecting, analysing, reporting, interpreting, reviewing and acting on performance data."	Neely *et al.* (1995) referred to in Melnyk *et al.* (2014, p. 175), and Bititci (2015, p. 29), among others.
Performance management	"[t]he cultural and behavioural routines that define how we use the performance measurement system to manage the performance of the organisation."	Bititci (2015, p. 29)
System of systems	A metasystem, comprised of multiple embedded and interrelated autonomous complex sub-systems that can be diverse in technology, context, operation, geography, and conceptual frame. These complex sub-systems must function as an integrated metasystem to produce desirable results in performance to achieve a higher-level mission subject to constraints.	Bourne *et al.* (2018a, pp. 2788–2789)

This multidisciplinary dilemma is widely recognised, as in Neely's (2005) review of the performance measurement research addresses, for example:

> *The most widely cited authors in the field come from a variety of different disciplinary backgrounds – accounting, information systems, operation management and operations research. It would not be surprising for the people from these different disciplines to tackle different research questions, building on different theoretical bases and employing different methodological approaches.*

> *The resultant task of integrating the knowledge generated by such a diverse group of scholars to enable the development of a coherent and agreed body of knowledge for the performance measurement community would inevitably be a significant challenge.* (Neely, 2005, pp. 1268–1269)

2.1.4 A balance between control and empowerment

Following the development of integrated performance measurement models, some authors questioned to what extent PMS lead to improved performance (Franco-Santos and Bourne, 2007), and have unintended consequences (Franco-Santos and Otley, 2018) and limitations (Nørreklit, 2000). The discussion in the literature recognises performance measurement as a process (Neely *et al.*, 2000), and how performance measures are used to manage organisations' performance (Bititci *et al.*, 2012; Lebas, 1995; Melnyk *et al.*, 2014). Researchers also acknowledge that contingency factors – including organisations' size, structure, culture, management style, system maturity, and ICT (Bititci *et al.*, 2004; Ferreira and Otley, 2009; Garengo *et al.*, 2007a; Otley, 1999) – influence the success or failure of a PMS.

Anthony and Reece (1975, p. 458) state that "*Control* is assuring that desired results are attended". In management accounting, it is recognised that this can be achieved in many different ways. Simons (1995b) addresses the managerial challenge of creating a management control system that balances command-and-control management style and empowerment, through suggesting four levers of management controls. These are:

- Belief systems define the purpose and common values.
- Boundary systems define the limits of creativity and decisions in the form of policies and procedures.
- Diagnostic systems define the measures to ensure that goals are achieved.
- Interactive systems define arenas for involvement and participation to cope with strategic uncertainties.

How to balance command-and-control and empowerment is a recurring dilemma in the PMM literature. Davenport (2006) argues that the goal with performance management should be learning and building knowledge rather than control. Hamel (2009) argues that command-and-control management styles reflect a mistrust of employees' competence and commitment. To a great extent, there seems to be a consensus in the literature discussion that empowerment is preferred; however, as Argyris (1998, p. 98) stated, "[m]anagers love empowerment in theory, but the command-and-control model is what they trust and know best".

Tessier and Otley (2012) review Simons' (1995b) four levers of controls and suggest a framework where management's intentions are achieved by combining the technical and social dimensions of the controls. Technical control is associated with the boundaries and diagnostic systems as they govern day-to-day activities, and includes cybernetic controls and procedures. Social control is associated with emotional elements and represents the manageable part of organisation culture, which includes belief and interactive systems.

In line with this thinking, Bititci (2015) associates the performance measurement dimension with the technical controls and performance management with social controls. This is recognised in Smith and Bititci's (2017) theoretical framework, which views performance measurement and performance management as two separate but interrelated dimensions (Bourne *et al.*, 2018b; Nudurupati *et al.*, 2021; Sardi *et al.*, 2019; Sardi *et al.*, 2020b).

Smith and Bititci's (2017) framework is chosen as the main framework for this thesis, as it is simple in its form and robust in use for analysing different organisations' practices and use of digital technologies. In comparison to others and more specific frameworks – e.g. the balanced scorecard (Kaplan and Norton, 1992, 1996, 2008) or Ferreira and Otley's (2009) framework for analysing PMS – it is not unilaterally focused on strategic alignment. It includes factors previous studies regarded as contingency factors, e.g. management style within the framework as part of the system. In particular it allows for a discussion on how management styles can vary from command-and-control to empowerment (Simons, 1995a) independent of what measures are defined. Smith and Bititci's framework is described in more detail in the following section.

2.2 A theoretical framework for PMM

Smith and Bititci (2017, p. 1208) recognise that "organisations are complex systems and theories that surround organisational control, managerial control and performance measurement have evolved from related but parallel fields". Building upon system theory and organisation control theory, they define performance measurement as "the process (or processes) of setting goals, developing a set of performance measures, collecting, analysing, reporting, interpreting, reviewing and acting on performance data", and performance management as "the cultural and behavioural routines that define how we use the performance measurement system to manage the performance of the organisation" (Smith and Bititci, 2017, p. 1209).

Following the development in the PMM literature, described previously, Smith and Bititci (2017) contribute to this discussion by suggesting a theoretical framework conceptualising how these two separate but interdependent dimensions, illustrated in Figure 1, can be used to identify, discuss, and develop the organisation's PMM system.

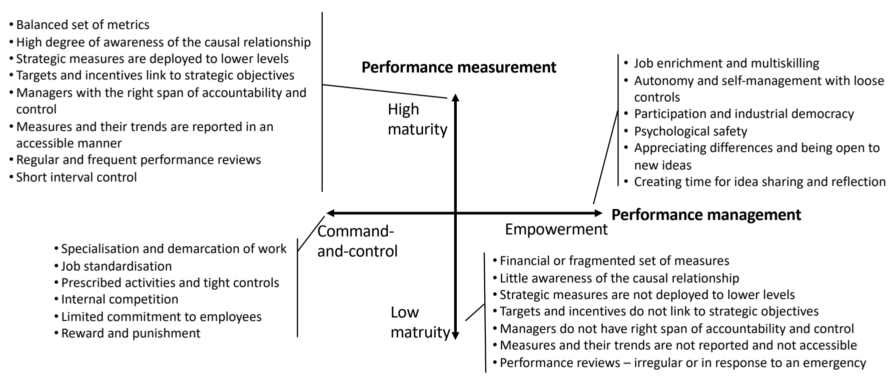

Figure 1: Smith and Bititci's (2019) Performance measurement and performance management theoretical framework

2.2.1 Performance measurement dimension

As illustrated in Figure 1, Smith and Bititci (2017) suggest categorising performance measurement according to maturity levels, where low maturity is associated with fragmented or only financial measures, limited awareness of causal relationships, lack of strategic linkage of measures to lower levels in the organisation, lack of relation between responsibility and measures, limited access to reports and trends, and no regular performance reviews. On the upper end of the maturity scale, the PMS reflects a balanced set of metrics and high awareness of causal relationships, lower levels' measures are associated with strategic goals, the span of accountability and controls fits with managers' responsibility, and reports and trends are accessible and used frequently in performance reviews. The existence of an organisations' PMS is often viewed as easy to analyse (Bititci, 2015); however, it is how the PMS is used that determines to what extent the organisation responds in line with management's intention (Bititci *et al.*, 2018; Tessier and Otley, 2012).

2.2.2 Performance management dimension

In Smith and Bititci's (2017) framework, the performance management dimension is a continuum of practices that spans from command-and-control to empowerment.[1] Command-and-control, as illustrated in Figure 1, is associated with tight controls in the form of specialisation of work, internal competition, and reward or punishment linked to performance. An empowering management style, however, promotes autonomy and participation, and discussions and sharing of new ideas (Smith and Bititci, 2017).

2.2.3 Interdependence between performance measurement and performance management

The Smith and Bititci´s (2017) framework enables a conceptualisation of the interaction between measures and how they are being used. The combination of the characteristics in the two dimensions illustrated in Figure 1 allows a typification of the controls. A start-up organisation with immature PMS combined with high autonomy, participation, and creativity can be typified as exercising charismatic control (Bititci, 2015; Nudurupati *et*

[1] Smith and Bititci (2017) use the phrase "democratic and participative"; however, I find "empowerment" more appropriate. "Democratic" is a strong word, associated with a form of government and how people have the authority to choose their governing legislations. In some organisational settings, it refers to formal regulations where union representatives are members of the board (Rolfsen, 2014).

al., 2021), whereas an organisation with a mature PMS combined with a command-and-control management style is associated with bureaucratic control. Autocratic controls combine low maturity with command-and-control, and mature PMS combined with an empowering management style is typified as collaborative control (Bititci, 2015; Nudurupati *et al.*, 2021). In Smith and Bititci's (2017) case study, they identified how an intervention in the performance management dimension – led by a group of employees who identified the need for an open and participative environment – resulted in minor but important changes to the performance measure dimension. They reduced the frequency of performance management review and started to use more aggregated measures, meaning a reduction in matureness in the performance measurement dimension. In this case, the organisation achieved a change in the performance management dimension toward more collaboration that had a positive effect on employees' engagement and performance.

Several researchers (Bititci *et al.*, 2018; Bourne *et al.*, 2018a; Garengo and Sardi, 2020; Nudurupati *et al.*, 2021; Okwir *et al.*, 2018; Sardi *et al.*, 2019; Sardi *et al.*, 2020b) have applied this framework, also to understand changes triggered by new (digital) technologies. However, before examining how digital technologies interact within this framework, a summary of how ICT have developed and their relation to PMM is appropriate.

2.3 From ICT to digital technologies

Access to data and information has been, and is now more than ever, an essential part of the PMM system (Bititci *et al.*, 2012). The organisation's management information system, "defined as a system that deals with the planning, development, management and use of information technology tools to help people perform all tasks related to information processing and management" (Garengo *et al.*, 2007b, p. 678), is widely studied (Dechow *et al.*, 2007; Garengo *et al.*, 2007b; Marchand and Raymond, 2008; Nudurupati and Bititci, 2005; Nudurupati *et al.*, 2011), and was previously viewed as a contingency factor for PMS (Garengo *et al.*, 2007a; Otley, 2016). In Smith and Bititci's (2017) framework, ICT can be viewed as part of the performance measurement dimension relating to collection, analysis, and reporting on measures (Nudurupati *et al.*, 2016; Sardi *et al.*, 2020b). There is obviously a relation between the available ICT and how performance and information data are used for decision making and aligning the organisation to their strategy, coordinating activities in the value chain, and facilitating continuous improvements and innovations.

When reviewing ICT development, there are parallels with the evolutionary path of PMM (Bititci *et al.*, 2012; Johnson and Kaplan, 1987) and other technological innovations (Bodrožić and Adler, 2017), illustrated in Figure 2. ICT is associated both with Industry 3.0 and Industry 4.0. In this section, I will address the distinction between Industry 3.0 and 4.0 with respect to the PMM system, as a PMM system without ICT support is said to be short-lived (Bititci *et al.*, 2012; Nudurupati and Bititci, 2005).

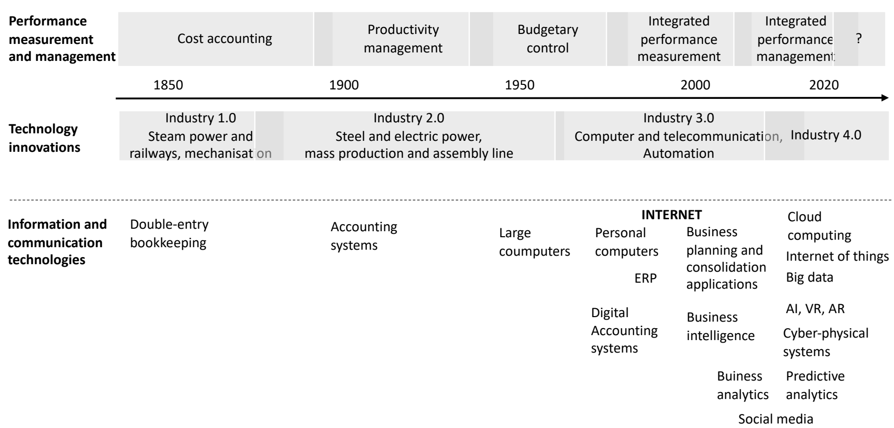

Figure 2: Parallel development of PMM, technology innovation, and information and communication technology.
Abbreviations: ERP – enterprise resource planning, AI – artificial intelligence, VR – virtual reality, AR – augmented reality.

2.3.1 Industry 3.0 and ICT

A significant change came with the internet, in around 1995. Along with the ".com" wave, a number of business applications with a central database and web-based access, e.g.

Cognos, Hyperion, and Business Objects, allowed sharing of performance data and simplification of performance measurement processes. These solutions supported the vertical alignment of the organisation to strategic goals (Ferreira and Otley, 2009; Kaplan and Norton, 2008), and increased diversity in measures used (Davenport, 2006). Enterprise resource planning (ERP) systems, e.g. SAP, Oracle, and Dynamics, promised a simplification of the horizontal coordination between departments (Davenport, 2006; Robert *et al.*, 2020). However, ERP systems have been criticised as expensive and complex to implement, cumbersome to use, and difficult to change (Dechow and Mouritsen, 2005; Jacobs and Weston Jr., 2007; Marciniak *et al.*, 2014; Nudurupati and Bititci, 2005; Nudurupati *et al.*, 2011; Sánchez-Rodríguez and Spraakman, 2012). Database-technology-enabled business intelligence, e.g. SAS, IBM, and Oracle, enabled efficient processing of large amounts of data from multiple sources (Peters *et al.*, 2016; Rikhardsson and Yigitbasioglu, 2018), giving new insight supporting continuous improvement and innovation (Bellisario and Pavlov, 2018). A commonality of ICT in the Industry 3.0 perspective is how it digitalised existing performance information and made it available in the applications.

2.3.2 Industry 4.0 and digital technologies

Industry 4.0 is used as an umbrella term and refers to changes related to the adoption and deployment of a combination of technologies. To distinguish between the ICT in Industry 3.0 and the technologies associated with Industry 4.0, I use the term "digital technologies". Digital technologies in the Industry 4.0 setting include cyber-physical systems, the internet of things, robotics, big data, cloud manufacturing, artificial intelligence, and augmented reality (Frank *et al.*, 2019; Robert *et al.*, 2020).

While Industry 3.0 enabled automatisation of manual tasks by industrial robots, Industry 4.0 enables digital technologies' changes to cognitive tasks (Davenport and Ronanki, 2018; Robert *et al.*, 2020). For example, artificial intelligence and the use of big data can automate the planning and monitoring of operations, predict maintenance, and enable production without human interference (Brynjolfsson and McAfee, 2012; Davenport and Kirby, 2016; McAfee and Brynjolfsson, 2012). Digital technologies that assist, augment or simulate cognitive tasks, e.g. problem solving and decision making, or that can be used to achieve cognitive aims, e.g. increased understanding and new knowledge, are also referred to as "cognitive technologies" (Davenport and Kirby, 2016; Ienca, 2018; Walch, 2019) or "intelligent technologies" (Bailey and Barley, 2020).

A number of authors address the possibilities with digital technologies (Brynjolfsson and McAfee, 2014; Davenport and Kirby, 2016; Davenport and Ronanki, 2018; McAfee and Brynjolfsson, 2012), including how organisations can take advantage of big data (Dubey *et al.*, 2019; Kamble and Gunasekaran, 2019; Matthias *et al.*, 2017) and artificial intelligence (Fountaine *et al.*, 2019, 2021) to meet a more global competition, demanding customers, and increasing uncertainty (Bititci *et al.*, 2012; Melnyk *et al.*, 2014).

Literature reviews on digitalisation and digital technologies in the field of PMM (Sahlin *et al.*, 2019; Sardi *et al.*, 2020a) identify a broad discussion on the use of information systems and big data for informed decision making. According to Sahlin *et al.* (2019), the existing research can be categorised into two groups: one that explores competitive and dynamic environments, and the other that mainly addresses artificial intelligence, automatisation, and optimisation. Sardi *et al.* (2020a) identify that despite the increased interest in digital technologies over the last five years, there are limited studies explicitly investigating digital technologies and performance measurement or performance management.

2.3.3 Digital technologies as an intervention in the performance measurement dimension

Some researchers (Nudurupati *et al.*, 2021; Sardi *et al.*, 2019; Sardi *et al.*, 2020b) have used Smith and Bititci's (2017) framework for their analysis when studying changes triggered by digital technologies. Sardi *et al.*'s (2019) research of enterprise social networks identified how this technology enabled a maturity in performance measurement with real-time access to data and allowed for self-monitoring of activity reports. It also facilitated a shift toward empowerment, as it enabled continuous feedback, knowledge sharing, and discussion.

A recent study by Nudurupati *et al.* (2021), explored how emerging digital technologies including data-sharing, real-time communication, and big data analytics are impacting the PMM system. Performance measures are used more extensively to communicate to a wider number of people, allowing more involvement and participation. They propose that "the purpose of performance measurement is changing from monitoring and surveillance towards engagement and improvement" (Nudurupati *et al.*, 2021, p. 9), and positively influences the interactive system (Simons, 1995b) toward empowerment.

Sardi *et al.* (2020b) also explored how access to data and information allows the performance measurement dimension to advance in their research on digitalisation in small- and medium-sized enterprises. However, the question of whether digitalisation would lead to a more command-and-control or empowering management style remains unanswered.

To advance this discussion on how digital technologies interact with PMM, there are two issues that need to be addressed. First, previous use of Smith and Bititci's (2017) framework is based on the assumption of PMM as a single system or a holistic and monolithic system – as it consists of different interconnected parts to achieve a particular purpose and not as separate and independent systems (Bourne *et al.*, 2018a). However, the recent PMM literature acknowledges the complexity in organisations (Melnyk *et al.*, 2014; Okwir *et al.*, 2018), and how different PMM systems have been introduced in different departments or by interest groups at different times (Bourne *et al.*, 2018a; Malmi and Brown, 2008). Similarly, digital technologies offer a platform of applications that can be used separately in different PMM systems. To improve on this issue, I will introduce Bourne *et al.*'s (2018a) SoS perspective in the next section.

The second issue is how technologies, and digital technologies in particular, are addressed. The PMM literature recognises digital technologies as a contingency factor influencing both performance measurement and performance management. However, it rarely considers how organisations choose between technologies and how technologies are configured and adjusted when implemented and used. To address this, I extend the framework by introducing the idea of duality of technology (Orlikowski, 1992) in the last section of this chapter.

2.4 An SoS perspective

Melnyk *et al.* (2014) questioned how well the current PMM fits with an uncertain and changing environment. The dominant and traditional view of PMM is as a monolithic system, where centrally developed tools and techniques (Bourne *et al.*, 2018a) including budget, scorecards, deviation reporting, and performance reviews are cascaded throughout the organisation to achieve alignment (Franco-Santos and Bourne, 2007; Franco-Santos and Otley, 2018; Malmi and Brown, 2008).

Bourne *et al.* (2018a) look to the discussion in system engineering and complex systems literature (Ackoff, 1971; Keating *et al.*, 2015; Sauser and Boardman, 2015), and suggest adopting the perspective of SoS to meet the challenges brought by the increased complexity and uncertainty organisations are facing. An SoS perspective "assumes that a set of independent systems can be bundled together to produce a multitude of responses that can help decision makers navigate through the complexity and make progress" (Bourne *et al.*, 2018a, p. 2790). In this view, the PMM system is a collection of autonomous sub-systems that can be loosely coupled, allowing local adaptability and use of technology to fit with different purposes.

Bourne *et al.* (2018) compares the characteristics of autonomy, belonging, connectivity, diversity, and emergence that constitute SoS with the dominant monolithic view of PMM:

- Autonomy refers to how sub-systems are independent and can pursue their own goals, able to prioritise learning and adaption in contrast to top-down alignment and control.
- Belonging refers to how sub-systems freely choose to associate themselves with the SoS as a whole. Compared to a central design solution in which measures are cascaded down the organisational ladder, the sub-systems address specific problems and, depending on the nature of the problem, can choose to associate the sub-system with the larger SoS.

- Connectivity refers to the type of relationship that exists between the sub-system and SoS. Following the characteristic of belonging, the relationships are dynamically formed and not centrally designed. According to a monolithic view, the different parts of a PMM system are integrated and tightly coupled, whereas in an SoS view, they are loosely coupled and independent.
- Diversity refers to how the heterogeneity of sub-systems makes the SoS robust to meet the complexity of different views, processes, technology and functionalities, in comparison to a PMM system that favours homogeneity and consistency.
- Emergence refers to how new properties develop or evolve, enabling SoS to be agile and adjustable. This characteristic meets the increased challenges faced by a traditional PMM system based on budgets and forecasts in predicting the unstable and complex future. In an SoS perspective, managers would collect appropriate performance data from the sub-systems, enabling them to respond to and navigate in rough waters.

The characteristics of an SoS perspective expand Smith and Bititci‘s (2017) framework, as they allow us to analyse PMM as a collection of sub-systems and how each sub-system positions itself differently on both the performance measurement and the performance management dimensions. When studying digital technologies, an SoS perspective enables a diversity in the analysis, as sub-systems can adopt and utilise the technologies differently.

2.5 Duality of technology

To understand how digital technologies impact PMM, I argue that we need to understand how organisations choose between available digital technologies and how those technologies are adjusted or changed when implemented and in use. Organisation theory literature has well discussed how we view and understand technology development (Adler, 1992; Adler, 2011; Bailey and Barley, 2020; Barley, 1986; Bodrožić and Adler, 2017; Orlikowski, 1992; 2000).

One view, referred to as the technological imperative model (Orlikowski, 1992), treats technology as a an independent factor influencing employees' behaviour and organisations' properties. Contingency models (Woodward, 1980) are a variant of this model, in which technology is a contextual factor influencing the organisational structures and performance.

An opposite view, referred to as strategic choice model (Orlikowski, 1992), views technology as a result of ongoing human actions (Zuboff, 1988), design, and use. In this perspective, technology is not accepted as a given, but rather a result of managers' and employees' choices. As Zuboff (1988) addresses, information technology can be designed with different intentions, "to automate and to informate" (Zuboff, 1988, p. 390), which will have different effects on employees, who become more controlled or empowered.

Orlikowski (1992) argues for a view of technology as either an external object or a result of strategic choices, and introduces the idea of duality of technology – where technology is developed by people and thereby influenced by their experience and perception in design, and used by people through actions. Orlikowski describes the duality of technology as follows:

> *Technology is the product of human action, while it also assumes structural properties. That is, technology is physically constructed by actors working in a given social context, and technology is socially constructed by actors through the different meanings they attach to it and the various features they emphasize and use. However, it is also the case that once developed and deployed, technology tends to become reified and institutionalized, losing its connection with the human agents that constructed it or gave it meaning, and it appears to be part of the objective, structural properties of the organization.* (Orlikowski, 1992, p. 406)

By this, Orlikowski (1992) argues for viewing technology in the interrelation between *peoples' actions* (the designers', users', and decision makers'), *the technology* (the artefact facilitating work), and *the organisation's structural properties*, including its structure, strategy, ideology, culture, controls, knowledge, and communication patterns, as well as the external environmental factors of rules and regulations, competition, and vendors. Figure 3 illustrates these relationships.

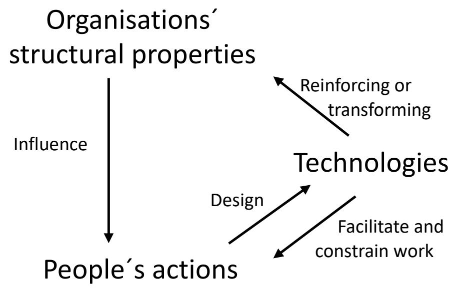

Figure 3: Orlikowski's (1992) duality of technology

Adopting a duality of technology view when researching how PMM interact with digital technologies advances the analysis of how existing PMS and performance management practices influence the adoption of digital technologies. For example, digital technologies, such as big data that contains software for databases and algorithms to analyse large amounts of information, can be viewed as a set of generic technologies created by designers in different times and places than their users, whereby the organisations choose how to implement these technologies. Bailey and Barley (2020) argue that digital technologies can be used as "artificial intelligence" to automate cognitive tasks, or as "augmented intelligence" to "complement and assist workers in their tasks" (Bailey and Barley, 2020, p. 3). Following Orlikowski's (1992) idea of duality of technology, how the organisations choose to deploy digital technologies such as big data will be influenced by the experiences of both those who design and those who use the digital solution.

3 Methodology

This thesis is founded in four articles using a qualitative approach, with three case studies and one multi-case study (Yin, 2014) employed to explore the phenomenon of PMM and digital technologies in manufacturing organisations. This methodological approach was selected because the aim of the study is to understand the organisations' PMM systems and how digital technologies are deployed and used in the PMM processes. To achieve this, we need to understand people's experiences, and how they interpret, reflect, and act on the PMM system(s). A case study approach, including methods of in-depth interviews and observations, generates richness and in-depth understanding (Cresswell, 2012; Seidman, 2013). When asking "how" a process operates and studying the dynamics in organisations' processes, a qualitative research approach is appropriate (Graebner *et al.*, 2012; Yin, 2014).

There are different views on how organisations work. As described in the theory chapter, performance measurement literature tends to build upon an engineering tradition, where it simplifies the organisational complexity into a mechanical view, as stated in the maxim "what you measure is what you get" (Kaplan and Norton, 1992, p. 71). To some extent, this approach excludes how people reflect on the performance measurement system, and finds ways of manipulating the system (Franco-Santos and Otley, 2018). Where engineers are primarily concerned with identifying workable solutions, the social science tradition is more concerned about people's experiences and actions in organisations (Cyert and March, 1963). This comes into view in the recent PMM literature, as it has evolved from discussing how to design and implement performance measures toward a more recent view on how measures are used and influenced by the organisational context and different management styles (Bititci, 2015; Bititci *et al.*, 2018; Nudurupati *et al.*, 2021; Smith and Bititci, 2017; Tessier and Otley, 2012). This thesis, including the four articles, positions itself in line with this more current view. In some ways, it also goes further by borrowing ideas from organisation studies, in particular the duality of technology.

In this chapter, I will explain the approach for selection of the case-study organisations and units of analysis, methods of data collection, the approach for data analysis, and summary of the main findings. But first, in qualitative research my interpretations and understanding are vital, and the research process is not linear (Yin, 2014). Therefore, I will start by reflecting on how my own experience has influenced the research, and how the research has been an iterative process that has changed course as it has progressed.

3.1 Research is influenced by one's own experience

> *Validity is not a commodity that can be purchased with techniques… Rather, validity is like integrity, character, and quality, to be assessed relative to purposes and circumstances.* (Maxwell, 1992, p. 280–281, referencing Brinberg and McGrath, 1985, p. 13)

To develop in-depth understanding of a case, a combination of multiple sources of data, such as interviews, observations, documents, and artefacts (Cresswell, 2012), is preferable. However, an interview is not only a method for data gathering: it is also a social relationship (Seidman, 2013). The researcher, myself, takes an active role in the interviews and observations, and even if I try to stay objective, my approach is influenced by my background and knowledge. Being transparent in how the research is conducted, data are interpreted, and theory is used, and to what extent the theory is transferable, are measures allowing the reader to consider the validity of the research (Maxwell, 1992).

My educational background includes graduating with a master's in business communication and a master's in economics and management accounting in 2002. My professional experience includes working as a management consultant in the interface between business processes, performance measurement systems, and ICT application implementations, before going into academia. This background has influenced my research in several ways.

On the positive side, the experience as a consultant has trained my ability to understand the dynamics in organisations, and how views on ICT applications and PMS may differ between disciplines and levels within an organisation. For me, researching across a disciplinary background was the initial thought for the thesis. When going into the case-study organisations, I stated as a requirement the need to include operators' views, including interviews and observations. My background has also given me experience in how to create relations with people, and in an interview situation create a setting where the informants felt comfortable to share their experiences. Experience in working with both business processes and configuring ICT applications, including applications used by some of the case-study organisations, allowed me to understand in depth how this application facilitated or constrained work when informants expressed their satisfaction or frustrations.

A more challenging side is how my personal background influences my views; this becomes a potential limitation in interpretations and reflections of the data collected as they relate to the phenomenon studied. For example, in my consulting practice, I'm trained to facilitate the solving of problems and to find solutions, not to theorise and reflect. In addition, the terminology used is to connect with the client, which becomes imprecise in a scientific context. To cope with these challenges, I took two main measures. Firstly, I discussed my interpretations and reflections with peers: in particular, my supervisor, who has challenged my views and made me test different reasonings, and become co-author on three of the articles. I have sought confirmation of my interpretation from key informants by presenting initial results and findings in internal seminars. In addition, I have exposed my views and interpretations by presenting at seminars, both at the Performance Measurement Association, and in fora where practitioners and academia meet. Secondly, to broaden my views and understanding of PMM as a phenomenon, I reviewed PMM literature from different disciplines, including related discussions in organisations' theory and digital transformation, as a continuous process when analysing and writing articles.

Another challenge is related to the context of my research. The research is partly funded by a research consortium, where the case organisations participate together with other manufacturing and academic organisations. Their primary interest is to find solutions and document best practices, not necessarily to engage in academic publishing. In addition, the relations with the case-study organisations became part of my network and potential partners for future research, which could unintentionally influence how I discuss, expose, and explain their practices in the articles and thesis. I might have tended to put greater emphasis on the positive results and aspects. These challenges have been addressed in three ways. Firstly, I have presented my initial analysis and interpretation with my understanding of their practices to key stakeholders in the organisation. These have met their expectations of identification of best practises and improvement, and at the same time, I received confirmation of my interpretation. Secondly, I have used pseudonyms for the case-study organisations and the informants, creating a distance between a case-study organisation's practices and the article. The content in the articles focuses on the phenomenon in action, and not the personal aspects of who carries out the actions, even if I use direct quotes in the arguments of my findings. Thirdly, I have approached this dilemma with openness with the key stakeholders and sent them drafts of the articles before submission.

3.1.1 Qualitative research as an iterative process

The way this doctoral thesis developed illustrates how "[q]ualitative researchers often do not even know the theory they will anchor their insights on prior to collecting the data". (Bansal and Corley, 2012, p. 512). My work experience triggered me into the PMM discussion, while the discussions with peers and existing literature changed the aims of the research during the process. The first aim was to describe PMS in Norwegian manufacturing, and how organisations coped with the multidisciplinary interactions between accountants and engineers in practice. This investigation resulted in article 3, prior to the idea of analysing the empirical data within the framework of SoS (Bourne *et al.*, 2018a). Along the journey, through discussions, reviewing literature, and conducting interviews at Beta and Alpha (initially in that order), the phenomenon of how digital technologies are influencing PMM emerged.

Exposing my research during the process through seminars and in casual discussions with colleagues – in addition to the hours of discussions with my supervisor – has been highly important in the journey to expand my own understanding, identify the theories that have become central in this thesis, and form the story on how digital technologies are influencing the PMM system. To illustrate how this unfolded, imagine how I was sitting, analysing and writing by my desk at home during the cold winter's days when the Covid-19 pandemic had closed down any form of physical contact. Another PhD student called me to ask a trivial question, and we ended up talking about my research. He replied, on the summary of my initial findings, "This reminds me of Orlikowski, as we had in the organisation's theory course together". This made me review that paper, and through discussions with my supervisor, Orlikowski's research ideas made their way into the thesis as the analysis, writing of articles, and reviews existing literature cycled on, loop after loop. Later, in section 3.4, I present an illustration of the process of data analysis and developing the findings that seems well organised; however, if I were to illustrate how it played out in reality, it would look more like a bowl of spaghetti.

3.2 Selection of cases and unit of analysis

> *A hallmark of a good qualitative case study is that it presents an in-depth understanding of the case.* (Cresswell, 2012, p. 98)

The three case-study organisations, Alpha, Beta, and Gamma (pseudonyms), were purposely sampled (Cresswell, 2012) from a Norwegian research consortium where academics and practitioners meet to discuss a range of challenges for manufacturing organisations in a high-cost country. The consortium aims to be at the forefront of the future of manufacturing, and Industry 4.0 issues are therefore of high interest. The participating organisations are engaged in and desire to be early adopters of technological innovations and digital trends. Hence, regarding the extent to which digital technologies are adopted in Norwegian industry, I expected to find examples in these organisations, and thereby considered them suitable cases for this research question. Whether or not these cases are representative of a larger population is less of a concern, as the cases were selected with the aim of building or expanding existing theories.

The research proposal was presented to approximately 15 potential partner organisations in the consortium, of which five signed up and volunteered to participate in the research, meaning that they wanted to set aside time and make informants available for interviews, with the belief that through this process they would gain new insights about their companies. Out of the five cases, I identified three as relevant for the single case studies used in the three first articles, as a combination of their characteristics and the findings from analysis revealed a story worth sharing, with a potential to contribute to the discussions in literature. Together, the three cases also became illustrations of the contrasts of digitalisation in Norwegian industry. All three cases are located in rural locations in Norway with industrial traditions, and the organisations are viewed as an important part of the local society.

I identified the first case-study organisation, Alpha, as being highly digitalised, young, dynamic, and relatively small, with approximately 130 employees. Compared to the other organisations in the research consortium, Alpha was already mature in using Industry 4.0 technologies. Automatisation and digitalisation had been central to their business operations from their start-up in the year 2000. Alpha produces high-volume batches of similar products on a (today) fully automated production line. Their production can be described as near-continuous flow production, as setup between batches does not stop the production. Alpha's production and administration are co-located, and the organisation is perceived as flat, were informal dialogue across hierarchical levels is part of how they describe their operations. Alpha is the case for the first article.

The second case, Beta, is part of a traditional industrial group, with long industrial traditions. Through initial workshops addressing challenges with adapting digital technologies, they were recognised to be successful in their ongoing digital transformation. At the same time, I viewed Beta as being at the frontier of adopting a PMM system, and the company had been used as an example to be followed in local lean conferences. This industrial group is vertically integrated, including international operations. The unit of analysis in this research is limited to a production unit in an electrochemical plant with approximately 240 employees. The production is a continuous flow production, with 24-hour operation. Beta is the case for the second article.

The third case, Gamma, is a medium-sized organisation with approximately 740 employees and produces a number of highly technically advanced products. Their different production unit is fragmented and varies from large batches of standardised production to low-volume, highly customised production. Gamma is in a competitive, but politically influenced market, as the majority of their revenue comes from governmental purchases. Gamma is the case for the third article, and in the multi-case study they are contrasted against the other two cases, as I identified their utilisation of digital technologies was limited.

For a more comprehensive description of the cases, see article 4, which analyses and compares the three organisations' PMM systems and use of digital technologies.

3.3 Data collection

Researching how organisations use PMM includes going beyond the general system description, and into the details of how people both interpret and interact with the system(s). This depth of enquiry requires building trust and confidence, so the informants are willing to share their good and bad experiences and give as truthful an insight as possible.

3.3.1 Identification and recruitment of informants

The organisations participating in this research were recruited from a research consortium. During several seminars, I presented the research proposal and held informal conversations with managers of the organisations, thereby finding opportunities for cooperation that could be fruitful for both parties. Initially, I collaborated with five organisations; however, only three of them make the basis for this thesis. Before starting formal interviews, a planning meeting specifying the research interests and data need was conducted. I then identified the informants in the organisations in two ways. Initially, they were identified by the point of contact based on my description of likely persons of interest. This included middle managers, operators, and staff responsible for the PMM system. Secondly, during interviews, I identified new informants by a snowball method, where the informant identified further contacts.

3.3.2 Iterations of interviews and observations

Semi-structured in-depth interviews and observations were the main source of data for this research. To gain an in-depth insight into the organisations, avoid management bias (Eisenhardt and Graebner, 2007), and be able to understand the influence of local contexts (Alvesson, 2003), I conducted interviews and observations in iterations: interviews–observations–interviews. The first and initial interviews were with managers, e.g. a COO or CFO, who gave an overview of the PMM systems and how they (should) work. This was followed by a visit to the factory floor to observe the activities of operators and middle managers. This allowed me to relate operators' and middle managers' answers in interviews to the activities and decisions they made on the front line. These observations brought me insight into the organisational language, including three-letter abbreviations. In addition, it enabled me to adjust the questioning to their language and not be "too academic" when interviewing operators.

In addition to interviews and observations, I collected secondary data, and participated (on invitation) in a few workshops and meetings in the case-study organisations. The secondary data included data provided by the informants in the form of PowerPoint presentations, reports or policy documents, and data publicly available online in webpages, newspapers, and annual reports and financial statements.

3.3.3 Initial interview based on the Ferreira and Otley framework

I based initial interviews, where the aim was to explore PMM in Norwegian industry in general and the alignment between accountants and engineers in particular, on Ferreira and Otley's (2009) framework for analysis of PMS as an interview guide. The framework's 12 main topics are shown in Table 3.

Table 3: Interview guide based on Ferreira and Otley's (2009) framework

Key factor	***Question (Ferreira and Otley, 2009, p. 266–267)***
Vision and mission	1. What is the *vision and mission* of the organisation and how is this brought to the attention of managers and employees? What mechanisms, processes, and networks are used to convey the organisation's overarching purposes and objectives to its members?
Key success factors	2. What are the *key factors* that are believed to be central to the organisation's overall future *success* and how are they brought to the attention of managers and employees?
Organisation structure	3. What is the *organisation structure* and what impact does it have on the design and use of PMS? How does it influence and how is it influenced by the strategic management process?
Strategies and plans	4. What *strategies and plans* have the organisation adopted and what are the processes and activities that it has decided will be required to ensure its success? How are strategies and plans adapted, generated, and communicated to managers and employees?
Key performance measures	5. What are the organisation's *key performance measures* deriving from its objectives, key success factors, and strategies and plans? How are these specified and communicated, and what role do they play in performance evaluation? Are there significant omissions?
Target setting	6. What level of performance does the organisation need to achieve for each of its key performance measures (identified in the above question), how does it go about *setting* appropriate performance *targets* for them, and how challenging are those performance targets?
Performance evaluation	7. What processes, if any, does the organisation follow for *evaluating* individual, group, and organisational *performance*? Are performance evaluations primarily objective, subjective or mixed and how important are formal and informal information and controls in these processes?
Reward systems	8. What *reward*s – financial and/or non-financial – will managers and other employees gain by achieving performance targets or other assessed aspects of performance (or, conversely, what penalties will they suffer by failing to achieve them)?

Information flows, systems, and networks	9.	What specific *information flows* (feedback and feedforward), *systems*, and *network*s has the organisation in place to support the operation of its PMS?
PMS use	10.	What type of *use* is made of information and of the various control mechanisms in place? Can these uses be characterised in terms of various typologies in the literature? How do controls and their uses differ at different hierarchical levels?
PMS change	11.	How have the PMS altered in the light of the change dynamics of the organisation and its environment? Have the *changes* in the PMS design or use been made in a proactive or reactive manner?
Strength and coherent	12.	How *strong* and *coherent* are the links between the components of PMS and the ways in which they are used (as denoted by the above 11 questions)?

I selected this framework because it comprehensively covers numerous elements of the performance measurement dimension and is "useful as a holistic tool for examining the structure, operation and use of PMSs in organisations" (Bourne *et al.*, 2018b, p. 2015). However, after reviewing some of the initial interviews, I adjusted the framework with three main elements to be able to explore in depth the digitisation that the informants were concerned with and to better address the ongoing discussions in the PMM literature. Firstly, the framework did not bring in-depth insight on the ICT architecture supporting the PMM system and to what extent digital technologies were deployed. This is an expansion of questions 10 and 11. Secondly, following the first addition, I included a retrospective question on how the PMM system had evolved and change with digitalisation. Thirdly, after analysing the first interviews against existing literature, I decided to address the performance management dimension, including management style and cultural elements that Ferreira and Otley (2009) categorise as contingency factors, more specifically, as this dimension coincides with the concerns of the case-study organisations.

3.3.4 Interviews and observations in several rounds

I conducted the interviews and observations in several rounds. Summarised in Table 4, the first interviews were in March 2017, and the last in December 2020. For each case, there were at least two rounds of interviews. The first round focused on PMM in general terms, with the aim of getting to know the organisations, having an overview, and identifying any issues of interest. The second round was targeted toward a specific subject of interest, e.g. to get in-depth insight from operators on how they were involved in implementation of digital technologies and how this affected their work. For the final, multi-case article, I conducted follow-up interviews at Gamma. A number of the interviews that occurred between April and December 2020 were conducted on Teams, due to the Covid-19 pandemic.

Table 4: Overview of data collection

Organisation	**Data collection**	**Time period**
Alpha	7 in-depth interviews 2 visits to the factory floor	August 2019 to April 2020.
Beta	3 workshop participations 7 meeting observations 21 in-depth interviews 10 conversations with informants during factory visit 3 visits to the factory floor	December 2018 to October 2020.
Gamma	12 in-depth interviews 5 meeting/workshop observations 4 days observation of quality audit 4 workshop participations 3 visits to the factory floor	March 2017 to November 2018. Follow-up interviews in 2019 and 2020.

The majority of the interviews, with some exceptions in Gamma due to practical and confidentiality issues, were recorded and transcribed. Observation notes, including my own reflections, were taken shortly after the observations. In addition to the interviews and observations, key informants participated in workshops and other meetings where they shared their experience of PMM. This included two workshops a year in the research consortium, and a midway seminar for the thesis. Presentations and notes from the workshops are included in the data material.

3.4 Data analysis and findings

Data analysis for the thesis is the result of analysis of the data from the four articles in Part 2. As illustrated in Figure 4, each article's analysis is based on a two-step approach, with my own reflections, discussions with peers, and review of the ongoing discussion in the literature occurring between each step. As mentioned earlier, even if the illustration in Figure 4 and the research approach seem linear, this has been an iterative process (Yin, 2014) between data collection, analysis, reviewing relevant literature, and reflections and discussion. The initial phase of the analysis was exploratory, with the data analysed from the ground up, and then compared with existing models and concepts. Ideas and interpretations have been tested in discussion with peers, in dialogue with the informants to ensure that I didn't overemphasise their story, and in particular during the process of writing articles. As the fit between my findings and existing models only partially matched, I searched for other theories that could help to expand the use of the model or other models that I could anchor my research in. The result of this iterative process is illustrated in Figure 4, with the main models used in the first step and second step of the analysis for the case studies. These models have been presented previously in chapter 2.

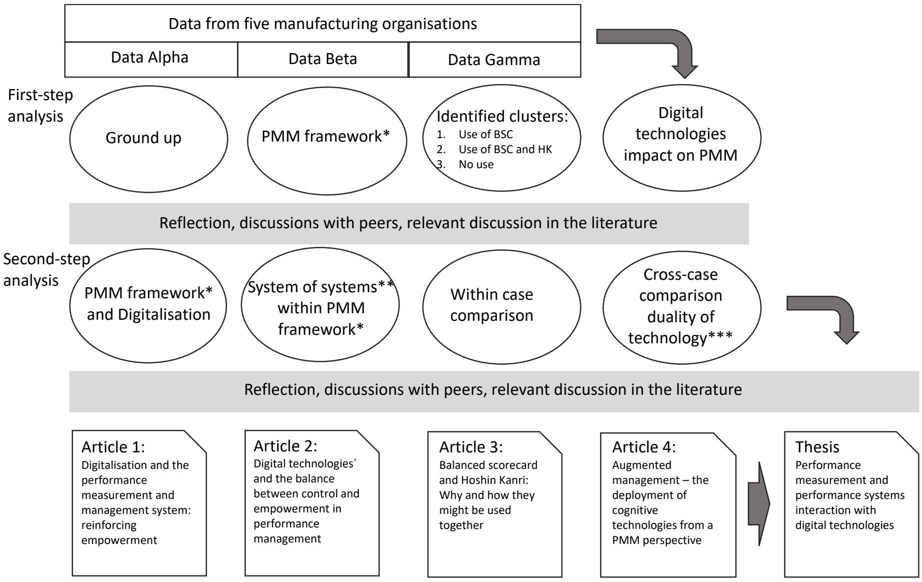

Figure 4: Illustration of data analysis leading up to the thesis.
Abbreviations: PMM – performance measurement and management, BSC – balanced scorecard, HK – Hoshin Kanri.
**Smith and Bititci (2017), **Bourne et al. (2018a), ***Orlikowski (1992)*

In the case of Alpha and article 1, the first round with interviews was analysed from the ground up, together with data from the four other organisations. This analysis indicated that Alpha had an extensive use of performance data and information from operators to top-management, which led to new interviews and a second analysis based on Smith and Bititci's (2017) framework. The analysis identifies how Alpha's approach to digitalisation reinforces existing empowering performance management practices.

In the case of Beta and article 2, the first step of analysis was the impact of digitalisation on "Team Performance" – a specific PMS for measuring the quality of manual tasks in production, based on Smith and Bititci's (2017) framework. During this first analysis, it became clear that Team Performance was only one of several PMS that the workers and managers related to in their daily work. Based on this insight, a second analysis was performed based on Bourne *et al.*'s (2018a) SoS perspective. The analysis identified how digitalisations can be deployed in a sub-system, independently of the other sub-systems, and increase the perceived empowerment without disturbing the balance between control and empowerment for the system as a whole.

I investigated the case of Gamma and article 3 prior to Alpha and Beta. The first ground-up analysis identified three clusters depending on their use of balanced scorecard only, balanced scorecard combined with Hoshin Kanri, or a group who didn't use either of the two. The second step of the analysis was an in-case comparison of the three clusters. The analysis identified how the two different PMS – balanced scorecard and Hoshin Kanri – complement each other. The balanced scorecard sets the strategic agenda, while through the "catchball" process in Hoshin Kanri, the goals are operationalised to lower levels in the organisations.

Article 4 is based on a multi-case analysis of the three cases. The first step of the analysis was to identify to what extent digital technologies are used and how they impact the PMM system. The anlaysis was based on a model in line with Smith and Bititci's (2017) PMM framework, with emphasis on the routines (Bourne *et al.*, 2018b) of vertical alignment of strategic goals, horizontal coordination in the value chain, and facilitation of innovation and continuous improvements. The second step was a cross-case comparison to identify any contextual factors that limited or enabled the deployment of digital technologies, different methods to approach implementation and deployment, and differences in how the use of digital technologies impacted work and managing performance. This part of the analysis adopted Orlikowski's (1992) idea of duality of technology. Table 5 gives a summary of the PMM practices and use of digital technologies. It contrasts how Alpha is highly automated and integrated, and makes data available across the organisations, while Beta is highly procedural and on a journey to adapting digital technologies, and Gamma makes limited use of digital technologies and is bound in existing legacy systems.

Table 5: Summary of cross-case comparison of PMM practices and use of digital technologies

Case	PMM practice	Use of digital technologies
Alpha	• Common understanding of production efficiency and lowering cost to be competitive and survive • Transparent use of information • Informal and formal communication across levels • Fully automated production line • Combines formal routines with digital applications • Digital monitoring augments employees in problem solving • All employees engaged in continuous improvements • Digital solutions free up time for middle managers • Digital communication secures structure and continuity to follow-up initiatives	• A web-portal with all data collected from multiple sources, including machines and sensors and other applications, such as ERP • Data available to everyone, across processes and hierarchies • Specific reports and monitors to support specific tasks – these augment users • Automatic monitoring gives alert of deviation from set targets. • "Shift log", a customised application for two-way communication between shifts • Data available across organisational levels, and on all devices
Beta	• Group defines the strategy, cascaded down, limited implication for production • Formal processes and routines • Staff-supported production system • Combines multiple PMM processes and tools • Order-based production • Digital systems schedules and coordinate activities • Focus on deviation from standards • Current lean practice since 2009 • Engaging operators to identify improvements • Piloting digital tools	• Independent applications • Combines dashboards and Excel • Staff to support data processing • ERP system and related applications • System to monitor production, gives alerts on deviations • Increasing use of production monitoring • Individual performance data used to augment operators' development • Middle managers' facilitation
Gamma	• Combines balanced scorecard for group with Hoshin Kanri for production • Quarterly formal processes • Middle-manager-dependent approach • Each order as a project • Project managers coordinate	• Detached applications • Primary Excel for targets and reports • Budget and financial reporting • ERP system supported with Excel • Stand-alone initiatives in single units

	• Collection of independent units • Initiated lean practice approach in production • Dedicated lean coordinator • Lean training and initiatives in units	• Ad-hoc analysis in Excel

4 Results – summary of the articles

This thesis is based on four independent articles that, in their own ways, contribute to the PMM discussion and provide theoretical and practical insights. In this chapter, I will give a short summary of each of the four independent articles, and how they contribute to this thesis. All four articles are included in full in Part 2 of this thesis.

4.1 Summary of "Digitalisation and the performance measurement and management system: reinforcing empowerment"

The article is a case study of Alpha, to explore how ICT can support PMM needs, and how it can contribute to empowerment in an Industry 4.0 setting. The research data, in the form of interviews and observations, was analysed based on Smith and Bititci's (2017) framework of PMM. This analysis identified how digital technologies matured the PMS. Alpha's approach to design and developing the ICT platform reinforced the existing performance management practices. Empowerment is strengthened when digital technologies enable automated collection, analysis, and reporting of performance data that free up middle managers' time so that they, together with operators, can drive continuous improvement. Middle managers change from "newspaper editors" spending time on data collection and selecting information for upward reporting, to facilitators, working side-by-side with operators to drive continuous improvement. Highlighting the role of middle managers in empowering operators through continuous improvement is novel in the PMM literature. A practical implication from the case is how Alpha relies on in-house, iterative ICT development and builds digital competence broadly.

The findings in this article contribute to this thesis on how PMM interact with digital technologies in three ways. First, they confirm that digital technologies mature the PMS (Sardi *et al.*, 2019). Second, the findings enlighten our understanding of how digital technologies interact with the performance management dimension toward command-and-control or empowerment (Nudurupati *et al.*, 2021; Sardi *et al.*, 2020b). In the case of Alpha, digital technology use reinforces existing management practice toward empowerment through continuous improvement. Third, Alpha chooses to deploy digital technologies as augmented intelligence (Bailey and Barley, 2020) to informate operators' and managers' decision making and problem solving, rather than to automate, deskilling and controlling the operators' work (Zuboff, 1988).

The article is co-authored with Jonas A. Ingvaldsen, and was submitted to the *International Journal of Productivity and Performance Management* in September 2020. As of July 2021, it is still in the review process.

4.2 Summary of "Digital technologies and the balance between control and empowerment in performance management"

In a manufacturing context, this article explores how the organisations' PMM systems are evolving when digital technologies are deployed, and whether they are used to promote command-and-control or empowerment-oriented performance management. It is based on research on a department in Beta that recently implemented a PMS supported by digital technologies to capture, analyse, and visualise close-to-real-time performance data on individual and teams, labelled "Team Performance". When "Team Performance" was seen in isolation, it was used to promote empowerment, and operators reported a significant increase in perceived psychological empowerment. However, the analysis identified how Beta uses numerous for tools for PMS in parallel. Adopting an SoS perspective enabled us to identify how "Team Performance" was only one out of several sub-systems, and as other parts of the organisation's PMM system remained control-oriented, the overall balance between control and empowerment remained stable. Building on the insights from Beta, we propose that digital technologies may be deployed to promote both command-and-control and empowerment within different PMM sub-systems in the same organisation. The likely contradictory effects of deploying digital technologies are best understood through an SoS perspective on PMM.

This article contributes to the thesis as the analysis of the PMM system is done by combining Smith and Bititci's (2017) PMM framework with Bourne *et al.*'s (2018a) SoS perspective. It enables identification of how digital technologies can impact a sub-system independently of other sub-systems. This degree of independence thereby gives management flexibility to test digital technologies and promote empowerment or increase control, without disturbing the overall balance in the PMM system.

This article is co-authored with Marte Daae-Qvale Holmemo and Jonas A. Ingvaldsen, and was submitted to *Measuring Business Excellence* in April 2021. As of July 2021, it is in the review process.

4.3 Summary of "Balanced Scorecard and Hoshin Kanri: Why and how they might be used together"

This article presents the case study of Gamma, which explores how the two PMM tools of balanced scorecard and Hoshin Kanri – associated with different disciplines – are used in parallel, and to what extent they can together improve strategic alignment. Based on the empirical findings from Gamma, the study demonstrates how Hoshin Kanri can complement the deployment of the balance scorecard at lower levels of the organisation for three reasons. First, it is associated with the "lean" concept that the operational level uses on a day-to-day basis. Second, the Hoshin Kanri matrix is a workable solution for linking long-term strategies to short-term goals. Third, it offers a "catchball" process that involves managers and employees on all levels in the strategy-deployment process.

Even if this does not address digital technologies explicitly (and shows signs of been written in the beginning the four-year research period), this study contributes to the thesis in two ways. First, it identifies how the PMM system is an evolutionary process where different sub-systems are created independent of each other to solve different managerial tasks. Hoshin Kanri was established on an operational level for goal alignment prior to the balance scorecard's application at a company level. Second, the article is also a good illustration of the qualitative methodology, where the process exploring a phenomenon takes the researcher into another direction than first anticipated.

The candidate is the single author of the Gamma case study, which has been published as a chapter in "Modeller, Fjordantologien 2019" (Helgesen *et al.* 2019). "Modeller" translates as "Models" as the theme for the publication.

4.4 Summary of "Digitalization studied from a performance measurement and management perspective – augmented intelligence?"

The fourth article is a multi-case study of Alpha, Beta, and Gamma. In light of Industry 4.0, it takes a PMM perspective and questions how Norwegian manufacturing deploys digital technologies (in the article, referred to as cognitive technologies), and explores the consequences for how work is performed and managed. The PMM perspective in the article combines the two dimensions of measurement and management in an SoS perspective (Bourne *et al.*, 2018a), and to simplify their organisation, categorises the sub-systems into three managerial processes (Bourne *et al.*, 2018b): vertical alignment of strategic goals, horizontal coordination of activities, and facilitation of innovations and continuous improvements.

From the three cases, three important findings are emphasised in this article. First, the organisations' deployment of digital technologies is incremental and bound to certain functions or sub-systems with limited implications for the organisation as a whole. This is a contrast to the view that Industry 4.0 and digital transformation lead to radical changes (Bughin *et al.*, 2018; Fountaine *et al.*, 2019; Pardi *et al.*, 2020). Second, we find that digital technologies do not replace work, but rather support middle managers and operators in problem solving and decision making. This use is what Bailey and Barley (2020) labelled augmented intelligence. The technologies reinforce existing cultures of empowerment and continuous improvement. This insight questions the prediction that artificial intelligence will replace cognitive work (Chamoni and Gluchowski, 2017), and that cultural transformation is required to exploit the new technologies (Fountaine *et al.*, 2019; McAfee and Brynjolfsson, 2012). Third, the companies build digital competencies by involving employees in the design and implementation of cognitive technologies. Employees become "bilingual" by adding digital language to the existing organisational language of production and process improvement. This approach overcomes the challenge of the cognitive technologies becoming "black boxes" (Davenport and Ronanki, 2018), and is an alternative to recruiting data scientists (Davenport and Patil, 2012).

This article can, to some extent, be seen as the "flip side" of this thesis, as it analyses the consequences of digital technology adoption in organisations from a PMM perspective. The key takeaway from this article is the short answer to the research question of how PMM interact with digital technologies. By comparing the cases, the study identifies how digital technologies are deployed in sub-systems in an iterative and involving process through design and use. As the article takes a technological approach, it introduces Orlikowski's (1992) duality of technology to explain how technology is influenced by people both in design and use. It identifies how digital solutions reinforce existing management practices that build upon continuous improvement where involvement and empowerment are key elements.

This article is co-authored with Jonas A. Ingvaldsen, and was submitted to *Beta – Scandinavian Journal for Business Research* in June 2021.

5 Discussion

This thesis builds upon three theoretical foundations: Smith and Bititci's (2017) framework, viewing PMS and performance management as separate yet interrelated dimensions; Bourne et al.'s (2018a) SoS perspective, which views the PMM system as a collection of sub-systems which are tightly or loosely coupled; and Orlikowski's (1992) duality of technology, which assumes that both technology design and use are influenced by people and their contextual setting.

Analysing the interaction between PMS and digital technologies in isolation, the findings from the three cases Alpha, Beta, and Gamma coincide to a great extent with similar research (Nudurupati *et al.*, 2021; Robert *et al.*, 2020; Sardi *et al.*, 2019; Sardi *et al.*, 2020b), finding that digital technologies enable a more mature PMS dimension. For example, automatic data collection gives access to detailed and frequent measures on lower levels in the organisations, and analysis of the data captured gives new insight into causal relationships. Based on the characteristics of digital technologies, and how these technologies are described in the management literature (Brynjolfsson and McAfee, 2014; Davenport and Ronanki, 2018; Fountaine *et al.*, 2019), these findings are expected.

By analysing how digital technologies are deployed, the empirical findings identify a pattern across the cases that digital technologies are deployed in sub-systems. According to the findings in the cases, organisations tend to limit the scope of the digitalisation projects to a single function or a sub-system. Through high involvement of in-house employees in design and implementation, existing organisational culture and management practices influence digital technologies. In use, we identify how digital technologies reinforce existing performance management practice, as in the cases' empowerment. These findings have two implications for the PMM field. First, addressing PMM as a collection of sub-systems gives us a more nuanced picture of how changes to the PMM system occur. Secondly, the findings challenge how researchers tend to treat technology in PMM research. These two implications are discussed in more detail before a summary suggesting areas for future research.

5.1 Sub-systems offer a more nuanced picture of how changes in PMM systems occur

Smith and Bititci's (2017) PMM framework offers a skeleton for analysing the interrelation between PMS and performance measurement practices. However, earlier studies of PMM take a monolithic system view (Nudurupati *et al.*, 2021; Robert *et al.*, 2020; Sardi *et al.*, 2020b), which assumes that different PMM processes are interconnected to meet centrally defined performance goals. Even if those studies provide us with useful insights on the overall trends, they do not address how the changes occur inside the organisations. Other studies limit the scope to a single system (Smith and Bititci, 2017), which offers valuable insight into the dynamics between performance measurement and performance management. However, in reality, organisations have developed a collection of performance processes and tools to deal with different complexities and uncertainties (Melnyk *et al.*, 2014) that parts of the organisation are facing, and these systems are more or less independent from each other.

By combining the Smith and Bititci (2017) PMM framework with Bourne et al.'s (2018a) SoS perspectives, we gain a more nuanced picture, which allows us to address the consequences that the deployment of digital technologies in a sub-system have on both the sub-system itself, and on the PMM system as a whole.

As illustrated in Figure 5, the PMM system in the case of Beta (see article 2 for the full study) consists of several sub-systems. Taking a single-system view of Team Performance revealed how it matured and promoted an empowering management style through feedback and learning (illustrated on the left of Figure 5). However, by zooming out, we were allowed to understand how Team Performance was limited to some operational tasks, while other PMM sub-systems governed other tasks (illustrated on the right of Figure 5).

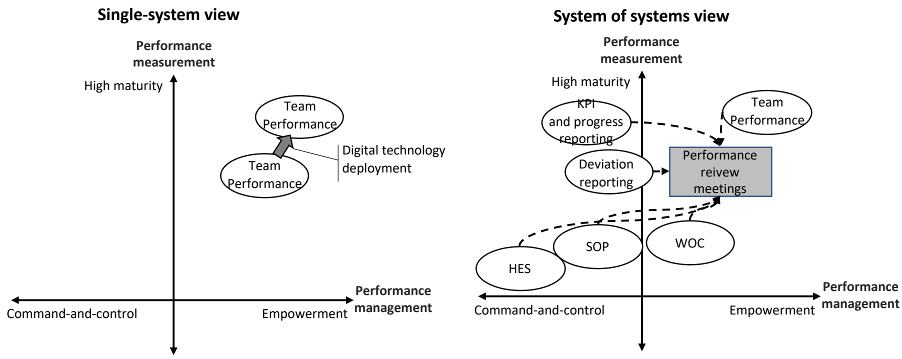

Figure 5. The research of Beta identifies how digital technologies interact in a sub-system, while the overall PMM system contains interactions between several sub-systems, here illustrated alongside Smith and Bititci's (2017) dimensions. Abbreviations: HES – health, environment, and safety, SOP – standard operating procedures, WOC – walk–observe–communicate.

The findings from the analysis of the empirical data from a sub-system perspective allows us to understand, firstly, how digital technologies may be deployed to promote both command-and-control and empowerment within different sub-systems in the same organisation. Secondly, the extent to which the sub-systems are tightly or loosely coupled is expected to influence the complexity in the deployment of digital technologies.

5.1.1 Sub-systems balancing control and empowerment

With an SoS perspective (Bourne *et al.*, 2018a) we can recognise the PMM development in an organisation as an evolutionary process where different sub-systems are created locally to meet managerial needs (Malmi and Brown, 2008) or adjusted to fit with the context they are used within (Melnyk *et al.*, 2014). Even if an empowering PMM system is desirable (Nudurupati *et al.*, 2021), it is reasonable to believe that different sub-systems could be more or less directive in nature. Some sub-systems promote empowerment (e.g. Team Performance in Figure 5), while others define the boundaries and are perceived as directive (e.g. HES in Figure 5). This perspective recognises the performance management dimension as a continuum of practices between command-and-control and empowerment (Smith and Bititci, 2017), where the sub-systems together create a balance between control and empowerment (Simons, 1995b).

Digital technologies can promote both controlling and empowering sub-systems. Analogous to Zuboff's (1988) consideration of how computer technology can be used to automate or informate, Bailey and Barley (2020) discuss how organisations can choose to deploy digital technologies as a form of artificial intelligence to automate information processing and decision making, or as a form of augmented intelligence to support operators and managers in their decision making. As described in article 4, the case organisations choose to use the digital technologies as augmented intelligence. The findings in Beta identified how change to Team Performance by implementing digital technologies had a positive impact and was perceived as empowering by the users of the sub-system, while it did not affect the balance of the PMM system as a whole. Assuming a similar logic for sub-systems that are more directive and controlling in nature, it will be possible for organisations that need to secure compliance and increase control to implement (or make changes to) a sub-system without shifting the overall balance. However, as control can be perceived as positive, negative, or neutral (Tessier and Otley, 2012), such logic is dependent on the involvement and the choices made when the sub-system is designed and implemented (or changed) and perceived when used.

5.1.2 Loosely coupled sub-systems reduce the complexity

In the case of Beta, the deployment of digital technologies in Team Performance did not affect the other sub-systems and had limited impact on the overall PMM system, as it was relatively loosely coupled. In Alpha, digital technologies were implemented to improve one function at a time, without disturbing the production. When approaching one sub-system or function at a time, the scope is limited and complexity is reduced compared to what is known from previous descriptions of holistic system implementations, such as ERP systems (Dechow and Mouritsen, 2005).

The extent to which the sub-systems are tightly or loosely coupled is expected to influence the deployment of digital technologies. Tightly coupled PMM systems are expected to be more challenging for digital technology deployment, as they require greater technology integration and organisational alignment. On the other hand, a more loosely coupled system would allow a greater diversity for both technology and practices.

5.2 Digital technologies are influenced by and reinforce existing management practice

The findings in the research of this thesis identify that digital technology adoption is influenced by existing practices both in design and use. This has consequences for how we view technology in the PMM discussion. Often, PMM research consciously or unconsciously takes a technology-imperative view (Orlikowski, 1992), where technology is considered an external factor that influences what the proper PMM design should be (Garengo *et al.*, 2007b; Nudurupati and Bititci, 2005). This thesis adopts duality of technology (Orlikowski, 1992) as a theoretical resource to explain the interaction between PMM and digital technologies.

In line with duality of technology, those involved in the design phase have an expectation that the technology will improve their own or the intended users' work. In its use, the technology is expected to facilitate the work: for example, as described in article 1, Alpha continuously deployed digital technologies to improve their work, and by close collaboration between operators, middle managers, and technical staff during the design and implementation phase, the solutions facilitated their work in use.

The Alpha case offers a detailed insight into how *technology and PMM are connected through the activities of the middle managers*. Pre-implementation, middle managers spent time in collecting data and making analyses with the purpose of both upward reporting and identifying the potential benefits of improvement of ideas. When a business intelligence solution was implemented, it automated the relevant data collection, analysis, and reporting. The choices made during the design and implementation were influenced by middle managers' existing practices and built upon the idea to enhance performance through continuous improvement. Even if data processing was automated and data made available to both high-level managers and operators, the solution did not replace the middle managers. Instead, the digital technologies were used as augmented intelligence and enabled middle managers to spend more time facilitating continuous improvement activities together with the operators, thereby reinforcing existing empowering management practice.

An important factor in the PMM-technology connection is the time and distance between the design and use phases. Future users' level of involvement in design and the extent to which design and use are an iterative process both influence how users perceive the digital solution. On the other side, if the two phases are disconnected, the structures and experiences influencing those who design the solutions are probably different from those who will use the solution. This might be a partial explanation for how ICT implementation meets resistance in practice, for example, as ERP systems are often perceived as cumbersome and constraining in use (Nudurupati *et al.*, 2011).

Following the analysis of the cases based on duality of technology, the digital technologies influence the PMM in an iterative and evolutionary manner. It questions to what extent there is an ongoing digital "revolution" (Bughin *et al.*, 2018; Gonzalez *et al.*, 2019; Pardi *et al.*, 2020; Reyes *et al.*, 2016). However, from a long-term perspective, Bodrožić and Adler (2017) argue that technology innovations in the past have been a powerful factor in shaping PMM systems, as they adopt and adjust to any disfunctions over several cycles. In this view, this thesis only covers a short-term perspective and questions the speed and direction of the digital revolution. Based on the reasoning that deployment of digital technologies is influenced by and reinforces existing management practice, can reproduce existing and less well-functioning processes. To discover and adjust to this dysfunction, the organisations need feedback or corrections either from relations to the markets in which they operate or from onboarding new managers. The idea of duality of technology used in this analysis does not exclude the need for major procedural or cultural changes. Management can choose to deliberate on changing the organisational culture through training and Human Relation Management interventions (Hekneby *et al.*, 2020) to promote a particular use of the new technology.

5.3 Future research

Following the principle of duality of technology (Orlikowski, 1992), future research should stop viewing technology as a "black box" that forces the organisations in certain directions by questioning "what effect digitalisation will have on…". Rather, future research should ask who is using digital solutions to what purpose, and how they create changes to the PMM system and practices. This will continue to extend our knowledge on how PMM evolves together with digital innovations.

This thesis addresses how middle managers are highly involved in processes that deploy digital technologies and how they have an important role in connecting the technology to activities. Discussion of middle managers' roles in the PMM system are sparse in PMM literature, and future research is needed to understand how they influence the development of the PMM system.

As this thesis demonstrates, adopting an SoS perspective offers a more nuanced and detailed insight. However, one limitation to the research in this thesis is that all cases promote an empowering management style, and the extent of the digital technology adoption is within an empowering context. Additional cases that are oriented toward a command-and-control setting are necessary to confirm the proposition that digital technologies can reinforce any sub-system.

Compensations and bonuses linked to performance are thought to be a central factor influencing how the PMM system is used as intended (Franco-Santos and Otley, 2018; Smith and Bititci, 2017). As this research is based on Norwegian manufacturing organisations, where salaries are fixed and centrally negotiated, the data on this factor are limited. Future research of organisations with variable compensation linked to performance would be valuable to determine to what extent this influences the development of the PMM system and adoption of digital technologies.

The cases are also limited to a manufacturing setting, which in a traditional sense is dominated by physical tasks and is measurement driven (Melnyk *et al.*, 2014). Cases from other industries, e.g. financial services, where cognitive tasks dominate, are needed to build more robust theories. It is known that artificial intelligence can be adopted to automate customer services (Brynjolfsson and McAfee, 2014) and data processing (Schäffer and Weber, 2019). Additional research is needed to understand how these industries' PMM systems interact with digital technologies, and if this interaction follows a similar or a different path to that described in this thesis.

6 Conclusion and practical implications

The manufacturing industry is facing the Industry 4.0 and associated digital technologies. The existing literature leaves an impression that this will lead to significant changes to organisations (Davenport and Ronanki, 2018; Fountaine *et al.*, 2019; McAfee and Brynjolfsson, 2012) and radically change the nature of work (Bughin *et al.*, 2018; Gonzalez *et al.*, 2019; Pardi *et al.*, 2020; Reyes *et al.*, 2016). This thesis has explored **how performance measurement systems and performance management practice interact with digital technologies.**

By combining Smith and Bititci's (2017) PMM framework where performance measurement and performance management are viewed as two separate yet interrelated dimension, with Bourne *et al.*'s (2018a) SoS perspective, the empirical findings from the three cases from Norwegian industry identify that **PMM interact with digital technologies in sub-systems**. By also adopting Orlikowski's (1992) duality of technology the cases show how **the design of the digital solutions is influenced by existing practice, and reinforces exiting management styles in use**.

The thesis contributes to the PMM theoretical discussion in two ways. First, it demonstrates how combining Smith and Bititci's (2017) theoretical framework with an SoS perspective (Bourne *et al.*, 2018a) enables us to identify how the PMM system is a collection of sub-systems that secures a balance between control and empowerment. Through the empirical analysis, it identifies how it is possible to make changes to a sub-system, where the users report increased perceived empowerment, without disturbing the balance for the PMM system as a whole.

Secondly, adopting Orlikowski's (1992) duality of technology is a contrast to existing research, which tends to view technology as external or as a contingency factor. The cases in this research identify how existing PMM systems influence the technology deployment, and how PMM and digital technologies interact through an iterative and evolutionary process. To what extent there is an ongoing digital "revolution" could be questioned, as the case studies discover how existing management style is reinforced and used as augmented intelligence, not replacing jobs, but supporting operators and middle managers to solve problems, take decisions, and identify and implement improvement that increases performance.

Following this conclusion, there are two practical implications I will highlight. First, recognising that digital technologies are deployed in sub-systems reduces both the scope and the complexity in digitalisation projects. The organisation can choose to make changes to a sub-system or even add a sub-system to their portfolio to meet a specific need, and achieve increased control or empowerment within the specific sub-system without disturbing other sub-systems.

Secondly, following the duality of technology, the organisations' approach for adapting digital technologies requires involvement in the design and implementation, to close the time–space gap between design and use. Digital technologies and Industry 4.0 differ in this perspective from Industry 3.0. Digital technologies offer a technical platform in which the organisations utilise, design, and customise technology according to their needs. This is in contrast to digital solutions in the Industry 3.0 era, where the organisations and their users had to adopt the thinking of the software designers. The outcome of successful involvement is when the solution in use is perceived as facilitating and becomes an "invisible" part of the work (see article 1, and the case of Alpha as an example). In addition, involving employees makes them "bilingual", where they understand the digital language of their operations. This is probably a more durable solution than relying on consultants or replacing existing employees with data scientists.

References for part 1

Ackoff, R.L. (1971), "Towards a system of systems concepts", *Management Science*, Vol. 17 No. 11, pp.661-671.

Adler, P.S. (1992), Technology and the future of work, Oxford University Press, New York.

Adler, R.W. (2011), "Performance management and organizational strategy: How to design systems that meet the needs of confrontation strategy firms", *The British Accounting Review*, Vol. 43 No. 4, pp.251-263.

Alvesson, M. (2003), "Beyond neopositivist, romantics, and localists: a reflexive approach to interviews in organizational research", *Academy of Management Review*, Vol. 28 No. 1, pp.13-33.

Anthony, R.N. and Reece, J.S. (1975), *Management accounting principles*, R. D. Irwin, Homewood, IL.

Argyris, C. (1998), "Empowerment: the emperor's new clothes", *Harvard Business Review*, Vol. 76 No. 3, pp. 98-105.

Atkinson, A.A. (2012), *Management accounting: information for decision-making and strategy execution*, Pearson, Upper Saddle River, NJ.

Bailey, D.E. and Barley, S.R. (2020), "Beyond design and use: how scholars should study intelligent technologies", *Information and Organization*, Vol. 30 No. 2, pp.1-12.

Bansal, P. and Corley, K. (2012), "Publishing in AMJ—Part 7: What's different about qualitative research?", *Academy of Management Journal*, Vol. 55 No. 3, pp.509-513.

Barley, S.R. (1986), "Technology as an occasion for structuring: evidence from observations of CT scanners and the social order of radiology departments", *Administrative Science Quarterly*, Vol. 31 No. 1, pp.78-108.

Bayraktar, E., Jothishankar, M.C., Tatoglu, E. and Wu, T. (2007), "Evolution of operations management: past, present and future", *Management Research News*, Vol. 30 No. 11, pp.843-871.

Bellisario, A. and Pavlov, A. (2018), "Performance management practices in lean manufacturing organizations: a systematic review of research evidence", *Production Planning & Control*, Vol. 29 No. 5, pp.367-385.

Bititci, U. (2015), *Managing Business Performance, the Science and the Art*, John Wiley & Sons, Chichester.

Bititci, U., Bourne, M., Farris Cross, J.A., Nudurupati, S.S. and Sang, K. (2018), "Editorial: towards a theoretical foundation for performance measurement and management", *International Journal of Management Reviews*, Vol. 20 No. 3, pp.653-660.

Bititci, U., Carrie, A.S. and McDevitt, L. (1997), "Integrated performance measurement systems: a development guide", *International Journal of Operations & Production Management*, Vol. 17 No. 5, pp.522-534.

Bititci, U., Cocca, P. and Ates, A. (2016), "Impact of visual performance management systems on the performance management practices of organisations", *International Journal of Production Research*, Vol. 54 No. 6, pp.1571-1593.

Bititci, U., Garengo, P., Dörfler, V. and Nudurupati, S.S. (2012), "Performance measurement: challenges for tomorrow", *International Journal of Management Reviews*, Vol. 14 No. 3, pp.305-327.

Bititci, U., Mendibil, K., Nudurupati, S.S., Turner, T. and Garengo, P. (2004), "The interplay between performance measurement, organizational culture and management styles", *Measuring Business Excellence*, Vol. 8 No. 3, pp.28-41.

Bodrožić, Z. and Adler, P.S. (2017), "The evolution of management models: a neo-Schumpeterian theory", *Administrative Science Quarterly*, Vol. 63 No. 1, pp.85-129.

Bourguignon, A., Malleret, V. and Nørreklit, H. (2004), "The American balanced scorecard versus the French tableau de bord: the ideological dimension", *Management Accounting Research*, Vol. 15 No. 2, pp.107-134.

Bourne, M., Franco-Santos, M., Micheli, P. and Pavlov, A. (2018a), "Performance measurement and management: a system of systems perspective", *International Journal of Production Research*, Vol. 56 No. 8, pp.2788-2799.

Bourne, M., Melnyk, S. and Bititci, U. (2018b), "Performance measurement and management: theory and practice", *International Journal of Operations & Production Management*, Vol. 38 No. 11, pp.2010-2021.

Bourne, M., Neely, A., Mills, J. and Platts, K. (2003), "Implementing performance measurement systems: a literature review", *International Journal of Business Performance Management*, Vol. 5 No. pp.1-24.

Brynjolfsson, E. and McAfee, A. (2012), "Winning the race with ever-smarter machines", *MIT Sloan Management Review*, Vol. 53 No. 2, pp.52-60.

Brynjolfsson, E. and McAfee, A. (2014), *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*, W. W. Norton & Company, New York.

Bughin, J., Hazan, E., Lund, S., Dalström, P., Wiesinger, A. and Subramaniam, A. (2018), "Skill shift - Automation and the future of the workforce", McKinsey Global Institute.

Cappelli, P. (2020), "Stop overengineering people management – the trend toward optimization is disempowering employees", *Harvard Business Review*, Vol. 98 No. 5, pp.56-63.

Chamoni, P. and Gluchowski, P. (2017), "Business Analytics State of the Art", *Controlling & Management Review*, Vol. 4 No. pp. 8 - 17.

Chenhall, R.H. (2003), "Management control systems design within its organizational context: findings from contingency-based research and directions for the future", *Accounting, Organizations and Society*, Vol. 28 No. pp.127-168.

Chenhall, R.H. and Moers, F. (2015), "The role of innovation in the evolution of management accounting and its integration into management control", *Accounting, Organizations and Society*, Vol. 47 No. pp.1-13.

Cooper, R. and Kaplan, R.S. (1991), "Profit priorities from activity-based costing", *Harvard Business Review*, Vol. 69 No. 3, pp.130-135.

Cresswell, J.W. (2012), *Qualitative Inquiry and Research Design. Choosing Among Five Approaches*, Sage Publications, Los Angeles, CA.

Cross, K.F. and Lynch, R.L. (1989), "The “SMART” way to define and sustain sucess", *National Productivity Review*, Vol. 9 No. 1, pp.23-33.

Cyert, R.M. and March, J.G. (1963), *A Behavioral Theory of the Firm*, Prentice-Hall, Englewood Cliffs, NJ.

Davenport, T.H. (2006), "Competing on analytics", *Harvard Business Review*, Vol. 84 No. 1, pp.98-107.

Davenport, T.H. and Kirby, J. (2016), "Just how smart are smart machines?", *MIT Sloan Management Review*, Vol. 57 No. 3, pp.20-25.
Davenport, T.H. and Ronanki, R. (2018), "Artificial intelligence for the real world", *Harvard Business Review*, Vol. 96 No. 1, pp.108-116.
Dechow, N., Granlund, M. and Mouritsen, J. (2007), "Management control of the complex organization: relationships between management accounting and information technology", *Handbooks of Management Accounting Research*, Vol. 2 No. pp.625-640.
Dechow, N. and Mouritsen, J. (2005), "Enterprise resource planning systems, management control and the quest for integration", *Accounting, Organizations and Society*, Vol. 30 No. 7-8, pp.691-733.
Deloitte (2021), "2021 manufacturing industry outlook" Deloitte Development.
Demartini, M.C. and Otley, D. (2020), "Beyond the system vs. package dualism in performance management systems design: a loose coupling approach", *Accounting, Organizations and Society*, Vol. 86 No. 101072**,** pp. 1-16.
Dubey, R., Gunasekaran, A., Childe, S.J., Blome, C. and Papadopoulos, T. (2019), "Big data and predictive analytics and manufacturing performance: integrating institutional theory, resource-based view and big data culture", *British Journal of Management*, Vol. 30 No. 2, pp.341-361.
Eisenhardt, K.M. and Graebner, M.E. (2007), "Theory building from cases opportunities and challenges", *Academy of Management Journal*, Vol. 50 No. 1, pp.25-32.
Evans, J.R. and Evans, J.R. (2011), *Quality and Performance Excellence: Management, Organization, and Strategy*, South-Western Cengage Learning, Mason, OH.
Ferreira, A. and Otley, D. (2009), "The design and use of performance management systems: an extended framework for analysis", *Management Accounting Research*, Vol. 20 No. 4, pp.263-282.
Fountaine, T., McCarthy, B. and Saleh, T. (2019), "Building the AI-powered organization", *Harvard Business Review*, Vol. 97 No. 4, pp.62-73.
Fountaine, T., McCarthy, B. and Saleh, T. (2021), "Getting AI to scale", *Harvard Business Review*, Vol. 99 No. 3, pp.116-123.
Franco-Santos, M. and Bourne, M. (2007), "An examination of the literature relating to issues affecting how companies manage through measures", *Production Planning & Control*, Vol. 16 No. 2, pp.114-124.
Franco-Santos, M. and Otley, D. (2018), "Reviewing and theorizing the unintended consequences of performance management systems", *International Journal of Management Reviews*, Vol. 20 No. 3, pp.696-730.
Frank, A.G., Dalenogare, L.S. and Ayala, N.F. (2019), "Industry 4.0 technologies: implementation patterns in manufacturing companies", *International Journal of Production Economics*, Vol. 210 No. pp.15-26.
Garengo, P., Bourne, M. and Bititci, U. (2007a), "Towards a contingency approach to performance measurement: an empirical study in Scottish SMEs", *International Journal of Operations & Production Management*, Vol. 27 No. 8, pp.802-825.
Garengo, P., Nudurupati, S.S. and Bititci, U. (2007b), "Understanding the relationship between PMS and MIS in SMEs: an organizational life cycle perspective", *Computers in Industry*, Vol. 58 No. 7, pp.677-686.
Garengo, P. and Sardi, A. (2020), "Performance measurement and management in the public sector: state of the art and research opportunities", *International Journal of*

Productivity and Performance Management, Vol. ahead-of-print No. ahead-of-print.

Gonzalez, V.I., Milasi, S., Carretero Gomez, S., Napierala, J., Robledo Bottcher, N., Jonkers, K., Goenaga, X.e., Arregui Pabollet, E., Bacigalupo, M., Biagi, F., Cabrera Giraldez, M., Caena, F., Castano Munoz, J., Centeno Mediavilla, C., Edwards, J., Fernandez Macias, E., Gomez Gutierrez, E., Gomez Herrera, E., Inamorato Dos Santos, A., Kampylis, P., Klenert, D., López Cobo, M., Marschinski, R., Pesole, A., Punie, Y., Tolan, S., Torrejon Perez, S., Urzi Brancati, C. and Vuorikari, R. (2019), "The changing nature of work and skills in the digital age", Publications Office of the European Union, Luxembourg,

Graebner, M.E., Martin, J.A. and Roundy, P.T. (2012), "Qualitative data: cooking without a recipe", *Strategic Organization*, Vol. 10 No. 3, pp.276-284.

Hamel, G. (2009), "Moon Shots for management", *Harvard Business Review*, Vol. 87 No. 2**,** pp. 91-98.

Hekneby, T., Ingvaldsen, J.A. and Benders, J. (2020), "Managing adoption by cultural development: exploring the plant level effect of a 'Company Specific Production System' (XPS) in a Norwegian multinational company", *Journal of Industrial Engineering and Management*, Vol. 13 No. 2, pp. 402-416.

Helgesen, Ø., Nesset, E., Glavee-Geo, R. and Rice, P. (2019), *Modeller - Fjordantologien 2019*, Universitetsforlaget, Oslo.

IDC. 2019. *IDC Global ICT Spending Forecast 2020 – 2023,* available at: https://www.idc.com/promo/global-ict-spending/forecast (accessed 11 May 2021 2021).

Ienca, M. (2018), "Democratizing cognitive technology: a proactive approach", *Ethics and Information Technology*, Vol. 21 No. 4, pp.267-280.

Jacobs, F.R. and Weston Jr., F.C.T. (2007), "Enterprise resource planning (ERP) – a brief history", *Journal of Operations Management*, Vol. 25 No. 2, pp.357-363.

Johnson, H.T. (1981), "Toward a new understanding of nineteenth-century cost accounting", *The Accounting Review*, Vol. 56 No. 3, pp.510 - 518.

Johnson, H.T. and Kaplan, R.S. (1987), *Relevance Lost: The Rise and Fall of Management Accounting*, Harvard Business School Press, Boston, MA.

Kamble, S.S. and Gunasekaran, A. (2019), "Big data-driven supply chain performance measurement system: a review and framework for implementation", *International Journal of Production Research*, Vol. 58 No. 1, pp.65-86.

Kaplan, R.S. (1983), "Measuring manufacturing performance: a new challenge for managerial accoun", *The Accounting Review*, Vol. LVIII No. 4, pp.686-705.

Kaplan, R.S. (1984), "The evolution of management accounting", *The Accounting Review*, Vol. 59 No. 3, pp.390-419.

Kaplan, R.S. and Norton, D.P. (1992), "The balanced scorecard—measures that drive performance", *Harvard Business Review*, Vol. 70 No. 1, pp.71-79.

Kaplan, R.S. and Norton, D.P. (1993), "Putting the Balanced Scorecard to Work", *Harvard Business Review*, Vol. 71 No. 5, pp.134-147.

Kaplan, R.S. and Norton, D.P. (1996), "Using the balanced scorecard as a strategic management system", *Harvard Business Review*, Vol. 74 No. 1, pp.75-85.

Kaplan, R.S. and Norton, D.P. (2008), *The Execution Premium: Linking Strategy to Operations for Competitive Advantage*, Harvard Business Press, Boston, MA.

Keating, C.B., Padilla, J.J. and Adams, K. (2015), "System of systems engineering requirements: challenges and guidelines", *Engineering Management Journal*, Vol. 20 No. 4, pp.24-31.

Krajewski, L.J., Malhotra, M.K. and Ritzman, L.P. (2016), *Operations Management. Processes and Supply Chains*, Pearson, Boston, MA.

Langfield-Smith, K. (1997), "MANAGEMENT CONTROL SYSTEMS AND STRATEGY: A CRITICAL REVIEW", *Accounting, Organizations and Society*, Vol. 22 No. 2**,** pp. 207-232.

Lebas, M. (1994), "Managerial accounting in France – Overview over past tradition and current practice", *The European Accounting Review*, Vol. 3 No. 3, pp. 471-488.

Lebas, M. (1995), "Performance measurement and performance management", *International Journal of Production Economics*, Vol. 41 No. 1-3, pp.23-35.

Malmi, T. and Brown, D.A. (2008), "Management control systems as a package – opportunities, challenges and research directions", *Management Accounting Research*, Vol. 19 No. 4, pp.287-300.

Marchand, M. and Raymond, L. (2008), "Researching performance measurement systems", *International Journal of Operations & Production Management*, Vol. 28 No. 7, pp.663-686.

Marciniak, R., E.L. Amrani, R., Rowe, F. and Adam, F. (2014), "Does ERP integration foster cross-functional awareness? Challenging conventional wisdom for SMEs and large French firms", *Business Process Management Journal*, Vol. 20 No. 6, pp.865-886.

Matthias, O., Fouweather, I., Gregory, I. and Vernon, A. (2017), "Making sense of big data – can it transform operations management?", *International Journal of Operations & Production Management*, Vol. 37 No. 1, pp.37-55.

Maxwell, J.A. (1992), "Understanding and validity in qualitative research", *Harvard Educational Review*, Vol. 62 No. 3, pp.279-300.

McAfee, A. and Brynjolfsson, E. (2012), "Big data: the management revolution", *Harvard Business Review*, Vol. 90 No. 10, pp.60-66.

Melnyk, S.A., Bititci, U., Platts, K., Tobias, J. and Andersen, B. (2014), "Is performance measurement and management fit for the future?", *Management Accounting Research*, Vol. 25 No. 2, pp.173-186.

Neely, A. (2005), "The evolution of performance measurement research: developments in the last decade and a research agenda for the next", *International Journal of Operations & Production Management*, Vol. 25 No. 12, pp. 1264-1278.

Neely, A., Gregory, M. and Platts, K. (1995), "Performance measurement system design: a literature review and research agenda", *International Journal of Operations & Production Management*, Vol. 15 No. 4, pp.80-116.

Neely, A., Mills, J., Platts, K., Richards, H., Gregory, M., Bourne, M. and Kennerley, M. (2000), "Performance measurement system design: developing and testing a process-based approach", *International Journal of Operations & Production Management*, Vol. 20 No. 10, pp.1119-1145.

Nørreklit, H. (2000), "The balance on the balanced scorecard – a critical analysis of some of its assumptions", *Management Accounting Research*, Vol. 11 No. pp.24.

Nudurupati, S.S. and Bititci, U. (2005), "Implementation and impact of IT-supported performance measurement systems", *Production Planning & Control*, Vol. 16 No. 2, pp.152-162.

Nudurupati, S.S., Bititci, U., Kumar, V. and Chan, F.T.S. (2011), "State of the art literature review on performance measurement", *Computers & Industrial Engineering*, Vol. 60 No. 2, pp.279-290.

Nudurupati, S.S., Garengo, P. and Bititci, U.S. (2021), "Impact of the changing business environment on performance measurement and management practices", *International Journal of Production Economics*, Vol. 232 No. pp.1-15.

Nudurupati, S.S., Tebboune, S. and Hardman, J. (2016), "Contemporary performance measurement and management (PMM) in digital economies", *Production Planning & Control*, Vol. 27 No. 3, pp.226-235.

Okwir, S., Nudurupati, S.S., Ginieis, M. and Angelis, J. (2018), "Performance measurement and management systems: a perspective from complexity theory", *International Journal of Management Reviews*, Vol. 20 No. 3, pp.731-754.

Orlikowski, W.J. (1992), "The duality of technology: rethinking the concept of technology in organisations", *Organization Science*, Vol. 3 No. 3, pp.398-427.

Orlikowski, W.J. (2000), "Using technology and constituting structures: a practice lens for studying technology in organizations", *Organization Science*, Vol. 11 No. 4, pp.404-428.

Otley, D. (1999), "Performance management: a framework for management control systems research", *Management Accounting Research*, Vol. 10 No. 4, pp.363-382.

Otley, D. (2016), "The contingency theory of management accounting and control: 1980–2014", *Management Accounting Research*, Vol. 31 No. pp.45-62.

Pardi, T., Krzywdzinski, M. and Luethje, B. (2020), "Digital manufacturing revolutions as political projects and hypes: evidences from the auto sector", International Labour Organization, Geneva, ILO.

Peters, M.D., Wieder, B., Sutton, S.G. and Wakefield, J. (2016), "Business intelligence systems use in performance measurement capabilities: implications for enhanced competitive advantage", *International Journal of Accounting Information Systems*, Vol. 21 No. pp.1-17.

Ravelomanantsoa, M.S., Ducq, Y. and Vallespir, B. (2018), "A state of the art and comparison of approaches for performance measurement systems definition and design", *International Journal of Production Research*, Vol. 57 No. 15-16, pp.5026-5046.

Reyes, A., Bacani, C., Horch, D., Rienstra, D. and Walter, J. (2016). "World Economic Forum Annual Meeting 2016. Mastering the Fourth Industrial Revolution." World Economic Forum, Geneva.

Rikhardsson, P. and Yigitbasioglu, O. (2018), "Business intelligence & analytics in management accounting research: status and future focus", *International Journal of Accounting Information Systems*, Vol. 29 No. pp.37-58.

Robert, M., Giuliani, P. and Gurau, C. (2020), "Implementing industry 4.0 real-time performance management systems: the case of Schneider Electric", *Production Planning & Control*, Vol. No. pp.1-17.

Rolfsen, M. (2014), *Lean blir Norsk, Lean i den norske samarbeidsmodellen*, Fagbokforlaget, Bergen.

Sahlin, J., Angelis, J. and Olan, F. (2019), "Performance management systems: reviewing the rise of dynamics and digitalization", *Cogent Business & Management*, Vol. 6 No. 1, pp. 1-21.

Sánchez-Rodríguez, C. and Spraakman, G. (2012), "ERP systems and management accounting: a multiple case study", *Qualitative Research in Accounting & Management*, Vol. 9 No. 4, pp.398-414.

Sardi, A., Garengo, P. and Bititci, U. (2019), "Measurement and management of competences by enterprise social networking", *International Journal of Productivity and Performance Management*, Vol. 68 No. 1, pp.109-126.

Sardi, A., Sorano, E., Cantino, V. and Garengo, P. (2020a), "Big data and performance measurement research: trends, evolution and future opportunities", *Measuring Business Excellence*, Vol. ahead-of-print No. ahead-of-print.

Sardi, A., Sorano, E., Ferraris, A. and Garengo, P. (2020b), "Evolutionary paths of performance measurement and management system: the longitudinal case study of a leading SME", *Measuring Business Excellence*, Vol. 24 No. 4, pp.495-510.

Sauser, B. and Boardman, J. (2015), "Taking hold of system of systems management", *Engineering Management Journal*, Vol. 20 No. 4, pp.3-8.

Schäffer, U. and Weber, J. (2019), "Digitalization will radically change controlling as we know it" in Schäffer, U. (Ed.) *Behavioral Controlling*, Springer Gabler, Wiesbaden, pp. 159-168.

Seidman, I. (2013), *Interviewing as Qualitative Research: A Guide for Researchers in Education and the Social Sciences*, Teachers College Press, New York, NY.

Simons, R. (1994), "How new top managers use control systems as levers of strategic renewal", *Strategic Management Journal*, Vol. 15 No. 3, pp. 169-189.

Simons, R. (1995a), "Control in an age of empowerment", *Harvard Business Review*, Vol. 73 No. 2, pp.80-88.

Simons, R. (1995b), *Levers of Control: How Managers use Innovative Control Systems to Drive Strategic Renewal*, Harvard Business School Press, Boston, MA.

Smith, M. and Bititci, U. (2017), "Interplay between performance measurement and management, employee engagement and performance", *International Journal of Operations & Production Management*, Vol. 37 No. 9, pp.1207-1228.

Taylor, F. W. 1911 (2010). *The principles of scientific management,* New York, NY, Cosimo Classics.

Taticchi, P., Balachandran, K. and Tonelli, F. (2012), "Performance measurement and management systems: state of the art, guidelines for design and challenges", *Measuring Business Excellence*, Vol. 16 No. 2, pp.41-54.

Tessier, S. and Otley, D. (2012), "A conceptual development of Simons' Levers of Control framework", *Management Accounting Research*, Vol. 23 No. 3, pp.171-185.

Walch, K. (2019), "Why cognitive technology may be a better term than artificial intelligence", Forbes, available at: https://www.forbes.com/sites/cognitiveworld/2019/12/22/why-cognitive-technology-may-be-a-better-term-than-artificial-intelligence/?sh=5d029302197c (accessed 25 March 2021).

Womack, J.P., Jones, D.T. and Roos, D. (1990), *The Machine that Changed the World*, Free Press, New York.

Woodward, J. (1980), *Industrial Organization: Theory and Practice*, Oxford University Press, Oxford.

Yin, R.K. (2014), *Case Study Research: Design and Methods*, SAGE, Los Angeles, CA.

Zuboff, S. (1988), *In the Age of the Smart Machine: The Future of Work and Power*, Basic Books, New York.

PART 2

Digitalisation and the performance measurement and management system: reinforcing empowerment

Eirik B. Hamre Korsen
Assistant Professor/PhD candidate, Norwegian University of Science and Technology

Jonas A. Ingvaldsen
Professor, Norwegian University of Science and Technology

A reviewed version of this article was published in *International Journal of Productivity and Performance Management on 2. November 2021.* *https://doi.org/10.1108/IJPPM-09-2020-0488*

Abstract
Purpose – This study explores how information and communication technologies (ICT) can contribute to empowerment in an Industry 4.0 setting.
Design/methodology/approach – The results are based on a case study of a Norwegian manufacturing organisation that has highly automated production and an integrated ICT platform. Data analysis was guided by the Smith and Bititci (2017) framework for performance measurement and management.
Findings – When powered by advanced ICT, the performance measurement system matures. The design and development of the ICT platform also reinforce the organisation's existing performance management practices. Empowerment is strengthened when automated collection, analysis, and reporting of performance data free up middle managers' time so that they, together with operators, can drive continuous improvement.
Research limitations/implications –The findings are limited to a single-case study and require further testing for transferability to other organisations. Future research should explore whether performance management practices are also reinforced by ICT in more command-and-control-oriented organisations.
Practical implications – The paper suggests an alternative strategy of Industry 4.0 transformation for organisations committed to empowerment. Such organisations should rely on in-house, iterative ICT development and build digital competence broadly.
Originality – This article contributes to our understanding of how performance measurement and management are interrelated and evolve in the context of Industry 4.0. To the best of our knowledge, highlighting the role of middle managers in empowering operators through continuous improvement is novel in the performance measurement and management literature.

Keywords Performance measurement and management, Information and communication technology, Industry 4.0, Management information system, Empowerment, Middle managers

Paper type Research paper

The research is funded by The Research Council of Norway. The authors want to thank Professor Umit Bititci and Professor Heidi Carin Dreyer for their valuable feedback in the early stages of writing this article.

Introduction

Industry 4.0 implies rapid technology development within additive manufacturing, sensorics, cyber-physical systems, the Internet of Things (IoT), big data, business analytics, cloud manufacturing, artificial intelligence, simulation, and augmented reality (Frank *et al.*, 2019; Robert *et al.*, 2020; Trotta and Garengo, 2019; Sardi *et al.*, 2020a). In particular, new information and communication technologies (ICT) can automate the collection and analysis of large amounts of data and make information easily accessible across an organisation. Hence, on the face of it, ICT now offer a (partial) solution to what is considered one of the greatest challenges to performance management: to move away from directive command-and-control towards an empowering style of management, where both information and decision-making authority are shared (Bititci, 2015; Bititci *et al.*, 2018; Bourne *et al.*, 2005; Davenport, 2006; Hamel, 2009; Kolehmainen, 2010; Melnyk *et al.*, 2014, p. 513; Neely *et al.*, 2000).

Important enablers for a performance measurement system (PMS) are employees' access to data and an organisation's management information system (MIS) (Garengo *et al.*, 2007; Marchand and Raymond, 2008; Nudurupati and Bititci, 2005; Nudurupati *et al.*, 2011). The ICT platform that supports an organisation's MIS has historically been based on an enterprise resource planning (ERP) system, with independent management reporting and planning tools (Dechow and Mouritsen, 2005; Nudurupati and Bititci, 2005). MISs have been criticised for being static, with cumbersome and time-consuming data collection and reporting (Marchand and Raymond, 2008; Nudurupati and Bititci, 2005; Nudurupati *et al.*, 2011). Contemporary MISs utilise advanced business intelligence and analytics tools with more integrated and automated data collection and reporting (Peters *et al.*, 2016; Rikhardsson and Yigitbasioglu, 2018; Torres *et al.*, 2018; Vallurupalli and Bose, 2018). However, studies on how MISs based on Internet 4.0 technologies interact with performance measurement and management (PMM) practices (Bititci, 2015; Bourne *et al.*, 2018b; Melnyk *et al.*, 2014) are scant (Raffoni *et al.*, 2017; Rikhardsson and Yigitbasioglu, 2018; Sardi *et al.*, 2020a). In identifying a main future challenge for PMM research, Bititci *et al.* (2012, p. 318) asked: 'Are current ICT platforms capable of supporting future performance measurement and management needs? If not, how should they be designed, developed and configured?'

Based on a single-case study of a Norwegian manufacturing organisation, this study explores how ICT can support PMM needs (Bititci *et al.*, 2012; Sardi *et al.*, 2019; Sardi *et al.* 2020a), and how performance measurement and performance management are interrelated and evolve (Smith and Bititci, 2017). It describes the features of an integrated ICT platform and identifies how it is designed, implemented, and used. By focusing on middle managers as the main users of the PMM system and on the operators, who are measured and possibly empowered, the study answers Bourne *et al.*'s (2018b) call for research providing new insights into PMM from lower levels in organisations.

The case study shows how the design and implementation of ICT are influenced by and reinforce an existing PMM system. A major finding is how an integrated ICT platform with automated data collection and analytic capabilities can change the role of middle managers. Middle managers change from 'newspaper editors' spending time on data collection and selecting information for upward reporting, to facilitators, working side-by-side with operators to drive continuous improvement. The case company's choice of implementing ICT to support operators' and managers' decision-making stands in contrast to the digitalisation trend of predicting and automating decisions. Building on these findings, the study suggests an alternative strategy of Industry 4.0 transformation for organisations committed to empowerment.

The remainder of this paper is structured as follows. First, relevant studies on performance measurement and performance management are reviewed. Second, the methodology, including the context of the case company, is described. Third, findings from the empirical research are presented. Finally, the paper discusses the contributions, limitations, and implications.

Literature review

The PMM literature has evolved from a performance-measurement perspective towards a performance-management perspective (Bititci *et al.*, 2012; Bititci *et al.*, 2016; Bititci *et al.*, 2018; Bourne *et al.*, 2018b; Ferreira and Otley, 2009; Lebas, 1995; Melnyk *et al.*, 2014; Otley, 1999). Lebas (1995) described performance measures as simplified symbols expressing a complex reality, which can be reproduced, and performance management as how we interpret and use the measures, including training, teamwork, dialogue, shared vision, and management style. Performance measurement and performance management are two separate, yet interrelated dimensions (Bititci, 2015; Bititci *et al.*, 2016; Lebas, 1995; Smith and Bititci, 2017).

The literature review below follows the two dimensions of performance measurement and performance management. First, it reviews how ICT has developed and how it supports performance measurement and employees' access to performance data. Second, it deals with the performance management challenge of balancing control and empowerment, in light of recent technological developments.

Performance measures and increased data accessibility

Performance measurement can be defined 'as the process of quantifying the efficiency and effectiveness of action' (Neely *et al.*, 1995, p. 80). Smith and Bititci (2017) related performance measurement to technical control from organisational theory. In a PMS, the tasks of collecting, analysing, and reporting performance data are essential. Organisations with a mature PMS use a balanced set of metrics, have high awareness of casual relationships, link strategic and operational measures, report performance in an accessible manner, and have a short interval of controls with frequent performance reviews.

An MIS is identified as one of the critical factors in implementing a PMS (Bititci *et al.*, 2012; Bourne *et al.*, 2000; Garengo *et al.*, 2007; Nudurupati and Bititci, 2005; Nudurupati *et al.*, 2011). According to Garengo *et al.* (2007, p. 678), an MIS can be defined as a '… system for planning, developing and using the Information Technology [sic] tools that support company members in managing the information process'. An MIS supports the flow of information in an organisation, which includes upward reporting to management, passing strategies, goals, and directives downwards, and passing information horizontally between departments (Nudurupati *et al.*, 2011).

Prior to 1990, MIS technology was characterised by separate installations of ERP systems. Accounting systems had a central position, and enterprises measured only financial indicators (Marchand and Raymond, 2008). During the 1990s and early 2000s, more standalone MISs supporting specific needs for planning and balanced scorecard or dashboard reporting were developed, such as Hyperion Planning, Tableau, and Corporater. The combination of Internet technology, which enabled distributed use and central databases to be combined, and enterprise-wide solutions where one system supports multiple divisions (e.g. MS Dynamics, SAP, Oracle, and IBM) made the MIS more integrated (Bititci *et al.*, 2012).

Over the last decade, Industry 4.0 technologies have made the MIS even more integrated. Frank *et al.* (2019) divided these technologies into front-end and base technologies. Front-end technologies labelled 'Smart Manufacturing' are central to operational activities and enable vertical integration, virtualisations, automation, traceability, flexibility, and energy management (Frank *et al.*, 2019, p. 16). Vertical integration connects ICT systems across hierarchical levels of a company, from operators to middle managers and top managers, automating traditional reporting and supporting decision-making (Frank *et al.*, 2019). Base technologies—IoT, cloud computing, big data, and analytics—are the building blocks for the front-end technologies. IoT is the technology connecting sensors and computers in an internet environment. Cloud computing or cloud manufacturing enables employees' access to information and virtual representation of the manufacturing system from any location (Ren *et al.*, 2014; Robert *et al.*, 2020). A combination of robotics, sensorics, and connectivity of machines generates a large amount of both structured and unstructured data, which can be captured. This is referred to as big data (Frank *et al.*, 2019; Kamble *et al.*, 2020; Robert *et al.*, 2020; Sardi *et al.*, 2020a). Analytics refers to the utilisation of big data for business intelligence (Peters *et al.*, 2016; Raffoni *et al.*, 2017; Rikhardsson and Yigitbasioglu, 2018; Torres *et al.*, 2018; Vallurupalli and Bose, 2018). According to Sardi *et al.* (2020a), most research on big data and performance is done within the fields of computer science and engineering. Within the business, management, and accounting domains, research remains sparse.

In the interface between technical infrastructure and data use, previous studies have identified several technical challenges: data have been perceived as neither relevant nor up to date, data collection and analysis have been cumbersome and time consuming, and data from different sources are not linked properly or are in different formats (Marchand and Raymond, 2008; Nudurupati *et al.*, 2011; Psoinos *et al.*, 2000). Even if the technical challenges are overcome, the success of an MIS and a PMS is determined by how information is used (Eccles, 1991). How people choose to behave with respect to available performance information can either be positive in the form of proactiveness, confidence, and drive for improvements, or negative in the form of ignorance, resistance, or incorrect interpretation of information (Nudurupati *et al.*, 2011).

According to Marchand and Raymond (2018), effective use of a PMS requires the interaction with the MIS to be transparent and unimpeded and the representation from the system to be faithfully reflected and relevant, so that users can act on the information. Nudurupati and Bititci (2005) found that ICT can support a PMS by improving the process of identifying business improvement, facilitating managers' decision-making, and increasing transparency and visibility. However, Cappelli (2020) warned about how artificial intelligence and optimisation may disempower people. Sardi et al. (2020b) argued that, when a PMS matures, organisations may evolve either towards more command-and-control or towards empowerment. Their study identified the nature of an MIS and 'organizational culture and management style' as the main contingency factors in the direction of evolution of performance management practices.

Performance management and empowerment

Kaplan and Norton's (1992) maxim that 'what you measure is what you get' indicates how measurement can be used to influence behaviour. Bititci (2015, p. 29) defined performance management as 'cultural and behavioural routines that define how we use the performance measurement system to manage the performance of the organization'. An organisation's performance management can span from command-and-control to participative and empowering approaches (Bititci, 2015; Lewis *et al.*, 2019; Smith and Bititci, 2017). According to Wilkinson (1997), empowerment is about how employees are involved in and committed to contributing to an organisation. There seems to be consensus that a participative and empowering management style is preferable. The goal for how we use the measures should be to learn rather than to control (Davenport, 2006). Yet, as Argyris (1998, p. 98) argued, '[m]anagers love empowerment in theory, but the command-and-control model is what they trust and know best'. Similarly, Hamel (2009) identified one of the greatest challenges for management as the creation of an environment in which information is shared and employees are involved and empowered.

Despite an apparent consensus that empowerment is desirable, the term is often not specified precisely in the PMM literature. In the related literature on management accounting, two forms of empowerment are discussed: structural (Argyris, 1998; Baird *et al.*, 2018; Kirkman and Rosen, 1999; Lewis *et al.*, 2019; Wilkinson, 1997) and a psychological (Hall, 2008; Lewis *et al.*, 2019; Spreitzer, 1995; 1996; Thomas and Velthouse, 1990). Structural empowerment is delegation of the authority and power to make decision to others; usually, this is delegation from senior managers to other members in the organisation (Lewis *et al.*, 2019; Wilkinson, 1997). Psychological empowerment is employees' perception of being empowered (Lewis *et al.*, 2019; Spreitzer, 1995; Thomas and Velthouse, 1990).

An important form of empowerment in manufacturing organisations today is employees' involvement in continuous improvements (Hirzel *et al.*, 2017). Continuous improvement is a form of structural empowerment, whereby management creates a learning environment that enables employees to access relevant resources, information, and knowledge to perform and improve their tasks (Hirzel *et al.*, 2017; Leyer *et al.*, 2019). Continuous improvement is also a form of responsible autonomy by which employees take an active role in defining the rules and procedures that govern their work (de Treville and Antonakis, 2006). However, empowerment through continuous improvement does not mean absence of management. Managers, particularly middle managers, facilitate problem solving (Hermkens *et al.*, 2020; Ingvaldsen and Benders, 2016), mediate frontline reality with top management's vision, and 'serve as a team leaders who are at the intersection of the vertical and horizontal flows of information in the company' (Nonaka, 1994, p. 32).

The literature review can be briefly summarised as follows: On the one hand, there is an enormous development in ICT that makes performance data more available, potentially overcoming previous technical obstacles with MISs. On the other hand, how companies make use of this development to design and use ICT to enable empowerment has not been adequately described in the PMM literature.

Methodology

Selection and context of the case

A single-case study approach was selected to obtain in-depth insights (Yin, 2014). The case company was purposively sampled to research the phenomenon of interest. Norwegian Manufacture (NM, a pseudonym) was selected among five manufacturing organisations in a research consortium. NM was identified as having the highest Industry 4.0 maturity (Trotta and Garengo, 2019) with a high level of automation, an advanced ICT platform similar to a cyber-physical system, as well as an entrepreneurial reputation with short decision lines. Furthermore, NM had reportedly engaged and empowered employees. NM can be categorised as an SME (Garengo *et al.*, 2007) with approximately 130 employees. NM makes a high-volume product with limited customisation. The production of the polymer-based product can be described as involving a sequence of three main steps: chemical processing, assembly, and quality inspection. All the steps are organised within a single production line and extensively automated; it is close to a continuous flow process (Safisadeh *et al.*, 1996) as set-ups between orders do not interrupt the flow. When NM was established, automation and continuous improvement were central to the strategy. The company achieved a tenfold improvement in its output per working hour from the same production line during the first 20 years of operation. The company competes in a global market, exporting more than 90 percent of its production. Financially, NM has been profitable every year over the last 13 years. Operators' salaries in Norway are high compared to other countries; therefore, automation and robotics are necessary to remain competitive. Many of those who were hired in the start-up phase of NM remain in the organisation, and their entrepreneurial attitude and focus on continuous improvement remain part of the organisational culture.

Data collection

In-depth interviews and observations were performed in two rounds. The first round was carried out in August 2019, and involved a visit to the manufacturing plant, with a detailed tour guided by the head of production who was interviewed along with the CFO, who is also responsible for IT. In the first round, the interviews were based on the Ferreira and Otley (2009) performance management framework. During the analysis of the initial interviews, the use of and access to performance data emerged as a key theme, requiring collection of additional data.

In the second round, the interviews were more focused on PMM practices, the characteristics of the organisation, and how the ICT system and data were developed and used. This included both the current practice and the informants' retrospective reflections on how ICT systems and PMM practices had developed from the start-up in 2000. The second round of data collection was conducted by web/phone in March and April 2020 and consisted of interviews with two operators, one automation technician, and two middle managers. The informants were identified by the production manager based on availability and willingness to participate voluntarily. In addition, a virtual tour of the company's ICT platform and MIS was done online.

Data analysis

All interview data were recorded, transcribed, and analysed. The first two interviews were coded and compared with interviews from four other manufacturing organisations. Together with observations from the production facility, it was found that all NM employees, from operators to top management, had extensive access to performance data, and the interviews indicated a transparent culture with engaged employees. After the second round of data collection, all interviews and observations were analysed along Smith and Bititci's (2017) two main dimensions: (1) performance measurement, including the ICT platform, and (2) performance management, including empowerment. This analysis is summarised in Table 1 and described in more detail in the next chapters. It is important to note that the current ICT platform and the PMM practices result from an interactive evolutionary process. Table 1 does not show states before and after a specific intervention, but rather snapshots of an ongoing process of incremental change.

Table I – Summary of data analysis

	Start-up, 2000 Partially digitalised	Current, 2020 Highly digitalised
Performance measurement: the ICT platform characteristics	• Productivity and quality measures collected manually • Manual product controls • Data from PLCs collected in separate databases • Paper-based 'shift-log' • Limited access to data in ERP, paper-based production schedule, instructions manually updated • Limited access to data as it required high IT skills	• Detailed measures and monitoring of productivity and production quality by sensors and vision technology • Automated product controls • Data from PLCs and other applications integrated and visualised in standard formats through web-based technology • Digital 'shift-log' facilitates two-way dialogue; serves as knowledge database • ERP data available across functions, automatically updated production schedule • Easy access to data across applications
Performance management: middle management and operators' perspectives	• Strategic focus on improving production and productivity for competitiveness • Middle managers depend on reports from operators and IT-specialist • Middle managers central to stabilize production and improvement	• Strategic focus on improving production and productivity for competitiveness • Middle managers use less time on data collection and analysis • Middle managers' freed-up time on data collection used on improvements

	• Operators run production, machine set-up, manual quality controls, troubleshooting • Operators reliant on experience and help from co-workers/ middle managers • Operators spend time on manual reporting of operational issues • Culture is open and participative, with formal and informal meetings across hierarchical levels. Collective bonus pay-out for meeting productivity targets.	• Operators run production, perform preventive maintenance, identify improvements • Operators identify solutions based on data from previous cases • Operators use less time on reporting • Although operators' activities traced digitally, autonomy perceived in daily work • Culture is open and participative, with formal and informal meetings across hierarchical levels. No bonus schemes; rewards through social events.

Findings

The findings are divided into three main sections. The first section describes the ICT platform and how it was developed. The second section focuses on the middle managers and how their role has changed as reporting has become automated. The third section describes how the operators are influenced by the ICT development.

Performance measurement: the ICT platform

When NM began production in 2000, the company planned to create a fully automated production line that would capture data wherever possible. They did not have a legacy system, and they could adopt the latest hardware and software at that time. The development of the ICT platform can be characterised as an evolutionary approach, as new functionality and solutions were adopted incrementally along with the development of the organisation's skills and processes. However, until six years ago, only a few employees had access to the rich data gathered from the machines and the competence to interpret those data.

Table II: Summary of NM´s application of Industry 4.0 base technologies

Industry 4.0 base technologies (Frank *et al.*, 2019)	**NM's application**
Internet of things	All machines and sensors are connected online capturing data real-time
Cloud computing	Data and applications are shared with web-based technology, available on all devices.
Big data	A large amount of data is automatic collected from machines and sensors throughout the production, for every product produced, with a frequency close to every 10 seconds.

Analytics	Data is automatic analysed and relevant subsets are visualized to users in an understandable format, highlighting deviations from defined limits and trends.

NM's current ICT platform includes applications of Industry 4.0 base technologies (Frank *et al.*, 2019), summarized in table 2. As shown in in Figure 1, the platform integrates a large amount of data from multiple sources and makes these data available in real time to everyone in the organisation. Data are collected from the machines' process-logic controllers (PLC, the 'data-brain' of the machine) and sensors installed around the production line into central databases. In addition, data from the ERP system and in-house custom-built applications are visualised in real time through a web-based interface, together with the shift-log application to document any issues within production.

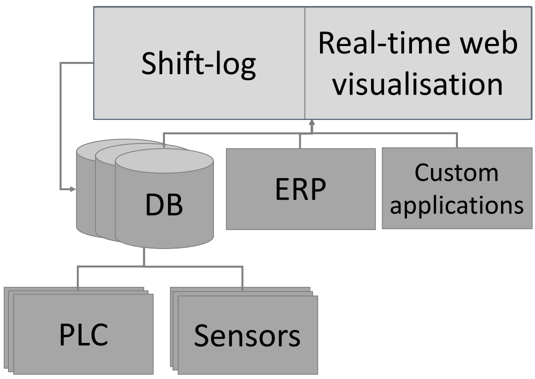

Figure 1 – Illustration of NM's ICT platform[1]

In a manufacturing organisation, a shift-log is a tool that supports horizontal coordination between shifts and functions, and vertical coordination between operators and middle managers. The shift-log is used for standard reporting at the end of each shift. It documents and reports any unexpected events, shows the status of production, and communicates ideas for improvements. When NM began in 2000, the shift-log and other central operational documents, such as the production plan and order specifications, were paper based. A paper-based system had some obvious weaknesses as it was time consuming and required strict version control to ensure everyone had the latest and correct information.

Today, the shift-log and all other operational documents are in a web-based application, which also visualises data from the machines, the ERP system, and other applications. This application is a single point of entry for the users to find all relevant information to support their work. As it is web-based, it is available on all devices, including mobile phones and tablets. In addition, relevant information is displayed on monitors throughout the production line. The data are available in real time and are relevant to monitoring the production line, controlling product quality, and scheduling and planning for set-up of new orders. Functionality in the reports with the shift-log enables users to drill both up and down in the data and to visualise the performance not only of a single machine or component but also of the entire production system. As the shift-log is digitalised and the data are stored in a central database, search for historic events or analysis of reoccurring events is possible. Furthermore, in the shift-log, there is functionality to track progress on a reported issue or improvement and to identify if it has been solved or rejected, and where it currently is in the plan-do-check-act cycle. All employees have access to the shift-log and can comment on any issue or improvements. It is an important two-way communication tool between operators and middle managers, and it provides information to support functions and top management.

The development of the ICT platform was done internally, creating ownership and competence. NM's approach to ICT development is to pilot small solutions that add to the existing platform. The aim is always to improve the production process, either through automation or by supporting the operators with relevant information. For example, a new automatic weight control of the product was developed in a collaboration between an engineer (Middle manager 1) and operators to ensure correct control procedures, parameter setting, and visualisation of the data that made sense to the users.

Performance management: the middle managers

Producing for a competitive market, NM depends on efficient production with high runtime. Improving and ensuring stability in production are central. In an advanced and automated production line that is running six shifts 24/7, the quality of the collaboration between operators and middle managers is crucial. Middle managers, who are responsible for a production cell, have a two-sided role in relation to operators. They need to ensure that operators on that cell are capable of running the production independently on the shift; at the same time, they need data and information from the production and operators in order to confirm that quality standards and production volumes meet expectations.

Middle managers access data and information from multiple sources. Data reported from the operators through the shift-log or directly in dialogue, data collected from the production line, and data from the ERP system constitute the main sources. Previously, these data were not easily available, as the shift-log was paper based and only a few automation engineers were able to access the production data. The automation of data collection, processing, and visualisation in an understandable format have made data easily accessible. This frees up time for middle managers for reporting and diagnosing production problems. The freed-up time allows the middle managers to spend more time on development, where, in conjunction with operators, coordination and facilitation of continuous improvement projects are central.

> *It has become easier to follow the production. It is easier to troubleshoot. It is easier to see which machines have been running or have had issues in the last 24 hours. ... So, I use less time to collect information from the operators. We can see on charts what has happened.* (Middle manager 2)

> *I used to be asked to investigate what happened by taking out data and analysing it. Now, these data are available to everyone, and I have more time to spend on product development and automation projects.* (Middle manager 1)

The digitalisation has also changed the shift-log from being a reporting tool to being a communication tool. It is used for communicating about issues in production where operators need assistance to find solutions or initiate an improvement. Since all relevant data are gathered in the shift-log, such as production plans and bills of material, misunderstandings are less frequent. The shift-log is used both diagnostically to identify issues and interactively by providing feedback to the operators on their reports or suggestions.

> *The shift-log, where most information is available, is used a lot by the operators. They report if they have any trouble, or just how the shift has been. If there has been anything extraordinary, they will report this too. Then we [the process owners] take action on this in morning meetings; if it's not critical, then they [the operators] call us. But we read it through before the morning meetings and find out what they need help with. And then we reply in the shift-log if things have been corrected or what goes on with it.* (Middle manager 2)

Performance management: the operators

At NM, operators are extensively involved in running and improving the production. Building competence and recruiting skilled operators who can take broad responsibilities were essential elements in the start-up 20 years ago, and they remain crucial. Management finds that this involvement and extended responsibility improves the efficiency and flexibility of the organisation, while also motivating the operators.

> *I think it is peculiar for NM that the operators are so involved and have so much to say, compared to [company name] where I used to work. … I think it was from the start that no one knew how to run the machines, so all operators were allowed to do everything, and we cannot take that away now because it would be boring to work here*. (Middle manager 2)

> *Improvement. To become better within own work and observe that the company is doing better. Much of the motivation is in it. Be able to make new products. Improve cycle times. It might sound boring for those who are not involved, but it is quite interesting.* (Operator 1)

The ICT development has aimed to improve communication in the organisation and to support the operators in monitoring and improving production. For example, the shift-log facilitates efficient communication and serves as a knowledge repository of previous incidents, which operators use to diagnose and solve current production problems.

> *We use it for communication, to the process owner and to the next shift, about issues that have occurred during the day. And, in addition, I use it to find solutions on issues. … Similar issues are most likely documented and referred to in the shift-log.* (Operator 1)

Other ICT monitoring equipment, such as cameras and vision systems, have been implemented to control and improve the quality of the products and the production process. Twenty years of improvement work have resulted in a fully automated production line where the cycle time has been reduced to one-tenth of the original time and the capacity is ten times higher.

> *The number of controls has increased. Now we have data systems, cameras, and a vision system that detect issues for us. So, the level of control has increased. But at the same time, the production is ten times faster now than before. So, it is necessary. We are not [manually] monitoring [production]when the cycle time is 8 to 10 seconds compared to 75 as it was before.* (Operator 1)

> *Earlier, a whole shift could go by before we detected a product error, which resulted in a large amount of rework. Now, we detect it instantly or within an hour.* (Middle manager 2)

The operators are trusted to run the daily operations and are central in the continuous improvement work. There are indeed several standardised tasks and controls that operators need to perform during a shift; however, it is up to them how they organise their time as long as the job is done.

> *We have fixed tasks we need to do every day ... but when and how we do it, and how we solve it within the shift, is completely up to us. As long as we get the job done, we decide when and how we want to do it based on how the production is running. ... No one comes and controls how we do it.* (Operator)

Operators regularly identify possible improvements. They are listened to and the suggestions are often implemented. The implementation of a continuous improvement initiative follows a standard plan-do-check-act methodology where every step is documented and reported in the shift-log. Hence, it is possible for the operator to follow the progress of the improvement suggestion independently of his/her shift. Management finds it important to credit the operator who has identified the improvement, which encourages others to seek improvements.

> *Most of the suggested improvements come from the operators.* (Middle manager 2)

Improvements often require the involvement of different roles, such as automation engineers, process engineers, and middle managers. Operators' involvement depends on their availability and to what extent they are affected by the change. In the weekly 'shift meeting' attended by middle managers and operators, the status and priority of improvement work is discussed. For large improvement projects, such as the installation of a new machine, the involvement of operators is a challenge, due to the shift work. To compensate for this, the project manager meets the operators across shifts to inform them and get feedback on the design.

It is a challenge that they [operators] work shifts and are seldom here during daytime, and it is difficult to involve a new operator each time. However, we are trying to involve them in the solution design, so they have a possibility to provide feedback. Because they can see if it is not going to work, as these are issues that they have had to struggle with for years. (Product manager)

In addition to formal meetings, there are many informal meeting places for operators and middle managers. The organisation is perceived as flat, and employees and managers meet over a cup of coffee or during lunch, where issues are discussed across hierarchical levels.

We have a relatively flat organisation. We have many 'coffee-meetings', the CEO and I, over a cup of coffee where we discuss and decide, as long as it is not a big investment. (Automation technician)

It is flat at NM, or it is perceived as flatter [than other organizations]. It is easier for an operator just to go and talk to the CEO. I believe it has much to do with the canteen. No one eats at a fixed time, but all eat between 10 a.m. and 1 p.m. and everyone talks with everyone. It is not divided into departments like many other places. (Middle manager 2)

Discussion

The results of this study contribute to debates on the interplay between performance measurement and performance management and how the two evolve together (Bititci *et al.*, 2018; Bourne *et al.*, 2018b; Sardi *et al.*, 2019; Sardi *et al.*, 2020b; Smith and Bititci, 2017). Smith and Bititci (2017, p. 1220) originally proposed that '… [p]erformance measurement and improvement interventions may be configured as social and/or technical interventions that can have a positive or negative impact on intended outcome'. Following this logic, we first discuss digitalisation as an intervention in the PMS and, second, we discuss its impact on performance management practices.

Digitalisation as an intervention in the PMS

Our results clearly support earlier findings that a PMS matures when it is powered by advanced ICT (Sardi *et al.*, 2019; Sardi *et al.*, 2020b; Smith and Bititci, 2017). The automatic data collection extents the scope of performance information beyond financial indicators, and enables a transparent use this information to support operators and manager's decision making.

NM's ICT platform integrates technologies which are often studied separately in the literature. A major difference between Industry 4.0 and 3.0 is how ICT becomes the enabling technology for manufacturing excellence (Robert *et al.*, 2020). NM is an example of how base and front-end technologies (Frank *et al.*, 2019) can be combined to support an efficient PMM system. For example, the shift-log combines the functionality of a traditional quality system, that is, to record and correct deviations from standards, with a two-way dialogue unconstrained by time and place, similar to an enterprise social network (Sardi *et al.*, 2019). Even greater effects are achieved when the shift-log functionalities are combined with IoT, cloud computing, big data and analytics (Frank *et* *al.*, 2019; Kamble *et al.*, 2020; Robert *et al.*, 2020; Sardi *et al.*, 2020a) making relevant information from the machines and sensors available to all employees. Together NM's ICT platform integrates a series of sub-systems (Bourne et al. (2018a) that facilitates and captures the formal and informal conversation related to problem solving. Workers, supervisors and technicians on different locations can then collaborate to solve unexpected issues.

Reinforcing empowering performance management

A manufacturing organisation like NM, with high volumes of standardised products, prescribed activities, standardised and specialised jobs, and extensive quality controls, can be measurement driven (Melnyk *et al.*, 2014) and is easily associated with a controlling management style (Smith and Bititci, 2017). However, the performance management practices at NM remain empowering. Furthermore, as the PMS maturity increased, the operators at NM engaged even more in decision making and problem solving. This finding is in line with Sardi *et al.*'s (2019) study, which proposed that web-based platforms that allow communication among workers, together with real-time data collection, analysis, and reports, encourage participative performance management. In addition, Roberts *et al.*'s (2020) case study on the implementation of Industry 4.0 technologies reported transparent use of performance information, increased responsibility, task enrichment, empowerment, and motivation at the first level.

To explain how digitalisation of a PMS reinforces empowerment, our analysis points to two main mechanisms. The first is the influence of what Sardi *et al.* (2020b) referred to as (the prevailing) 'organizational culture and management style'. Norms, values, beliefs, and ways of working (Jardioui *et al.*, 2019) that promote empowerment were established early in NM's history and continue to influence the daily behaviour of managers. They also influence how managers and engineers select, combine, and configure technological solutions (Bailey and Barley, 2020): for instance, the decision to give all employees the opportunity to read and comment on the shift-log.

The second main mechanism centres on the role of middle managers. It has received far less attention in the PMM literature. At NM, following the automatization of data collection, analysis and reporting, the middle managers' role changed from 'newspaper editors' providing information upwards, to facilitators working side-by-side with the operators to drive continuous improvements.

Middle managers have a central role in the PMM system (Jääskeläinen and Luukkanen, 2017; Jardioui *et al.*, 2019). Nevertheless, they have been squeezed between controlling and empowering subordinates (Ingvaldsen and Benders, 2020). To ensure control and to provide top managers with performance information, middle managers collect, analyse, and report performance data from various sources, or require subordinates to produce reports to ensure reliable information (Jääskeläinen and Luukkanen, 2017). Some commentators view this as the only task for middle managers, arguing that with modern ICT, they become redundant as senior management performs direct monitoring and control (Floyd and Wooldridge, 1994). The case of NM shows a different development trajectory. There, the development is in line with the view that middle managers are a resource to support frontline innovative activities (Nonaka, 1994; Wooldridge *et al.*,

2008) and that they are the linchpins of continuous improvement (Hermkens *et al.*, 2020; Holmemo and Ingvaldsen, 2016). Middle managers' renewed focus on continuous improvement prompted increased empowerment on the shop floor.

Limitations and future research

Findings from a case study are influenced by a specific context; therefore, they are not directly transferable to other organisations. Nonetheless, this study suggests themes and mechanisms to be explored further in future research.

A major finding of our study is how the nature of performance management (in this case, empowerment) is *reinforced* by how a company integrates ICT into its PMS. This argument is anticipated by Sardi *et al.*'s (2020b) contingency model, and more generally in the literature on how organisations design and make use of technology (Bailey and Barley, 2020). A key explanatory factor is organisational culture, which is fairly stable (Jardioui *et al.*, 2019). In so far as technological choices (and the associated organisational choices) reflect the existing management style and organisational culture (Sardi *et al.*, 2020b), an evolutionary pattern of reinforcement is likely to occur in both authoritarian and empowering organisations. On the other hand, organisations may choose to deliberately change the organisational culture through training and HRM interventions (Hekneby *et al.*, 2020) when realigning their PMM system. Additional research is necessary to achieve more robust theory building on reinforcement. For instance, would a contrasting case of an organisation with a command-and-control management style follow a similar path as NM did?

A closely related question is under what conditions Industry 4.0 technologies enable empowerment, as well as when these technologies do not. NM is a unique case as they did not need to take into account any old ICT systems, and could develop a forward-looking ICT platform based on online technologies which are compatible with industry 4.0 developments. Additional research should explore how organisations with a more complex ICT architecture, including legacy systems, adapts industry 4.0 technologies and how these technologies influence (or not) their PMS.

Finally, we encourage future PMM studies to explore in more detail what constitutes empowerment on the shop floor and how it originates. That would mean answering Bourne *et al.*'s (2018b) call for new insights into PMM from lower levels in organisations. Although empowerment is easily associated with worker autonomy (Argyris, 1998; Baird *et al.*, 2018; Bourne *et al.*, 2018b), other studies suggest that empowerment, especially through continuous improvement, is indeed actively managed, and requires a distinct management style (Hermkens *et al.*, 2020; Ingvaldsen and Benders, 2016; Nonaka, 1994). This raises questions about what exactly constitutes an empowering (middle) management style, how it can be measured, and how managers trained in a command-and-control environment can change their behaviour when the organisation decides to move towards empowerment.

Conclusion and practical implications

Industry 4.0 technologies such as cloud computing, IoT, and big data overcome previous obstacles to MISs and increase the maturity of PMSs (Sardi *et al.*, 2019). However, better and more precise measures can be put to different uses; digital interventions in a PMM system will be influenced by the existing management style and organisational culture. In the case of NM, digitalisation enabled a more empowering performance management practice through transparent use of information, job enrichment (Roberts *et al.*, 2020), and augmented intelligence (Bailey and Barley, 2020). A key finding is how automated data collection, analysis, and reporting freed up the middle managers' time and allowed them, along with the operators, to be a 'dynamo' for continuous improvements (Floyd and Wooldridge, 1994). At NM, the development of the ICT platform and the PMM system as an iterative process with high user involvement strengthened the existing performance management practices. Thus, digitalisation reinforced empowerment.

An empowering path towards Industry 4.0

Organisations embarking on Industry 4.0 transformation by relying on analytics and artificial intelligence for predicting outcomes and automating decisions (Raffoni *et al.*, 2017; Rikhardsson and Yigitbasioglu, 2018) are likely to reduce operators' autonomy (Schwarzmüller *et al.*, 2018), making them an extension to the computer (Cappelli, 2020). The case of NM shows an alternative, empowering path to Industry 4.0: one in which operators (and middle managers) are viewed as competent decision makers and problem solvers. NM chose an iterative and evolutionary approach to Industry 4.0, made data available, and facilitated a two-way dialogue on production improvement. Given other companies' desire to develop their performance management practices toward more empowerment, there are two practical lessons to learn from NM's approach.

First, NM's extensive involvement of employees throughout the digitalisation process strengthened their digital competence (Rikhardsson and Yigitbasioglu, 2018). It afforded the middle managers and operators a deeper understanding of the data, from the machine or sensor to the dashboard, creating a common understanding of the causes and effects, and aligning the interpretation of the information across occupational and hierarchical boundaries.

Second, NM recognised that ICT development was not only a technical exercise, but rather a (major) piece in the PMM development puzzle. Managers need to consider how to continuously improve their ICT as an integrated part of an organisation. The case of NM is an example where in-house ICT personnel are coupled with competent operational personnel to test and implement solutions that suit the needs of both the operators and managers. For larger projects or immature technologies, external consultants can bring in expertise and capacity.

Notes

1. Abbreviation in figure 1: DB - Data bases, ERP - Enterprise Resource Planning system, and PLC - Process-Logic Controllers (the 'data-brain' of the machine).

References

Argyris, C. (1998), “Empowerment: the emperor's new clothes”, *Harvard Business Review*, Vol. 76 No. 3, pp. 98-105.

Bailey, D.E. and Barley, S.R. (2020), “Beyond design and use: how scholars should study intelligent technologies”, *Information and Organization*, Vol. 30 No. 2, pp. 1-12.

Baird, K., Su, S. and Munir, R. (2018), “The relationship between the enabling use of controls, employee empowerment, and performance”, *Personnel Review*, Vol. 47 No. 1, pp. 257-274.

Bititci, U. (2015), *Managing Business Performance, the Science and the Art*, John Wiley & Sons, Chichester, West Sussex, United Kingdom.

Bititci, U., Bourne, M., Farris Cross, J.A., Nudurupati, S.S. and Sang, K. (2018), “Editorial: towards a theoretical foundation for performance measurement and management”, *International Journal of Management Reviews*, Vol. 20 No. 3, pp. 653-660.

Bititci, U., Cocca, P. and Ates, A. (2016), “Impact of visual performance management systems on the performance management practices of organisations”, *International Journal of Production Research*, Vol. 54 No. 6, pp. 1571-1593.

Bititci, U., Garengo, P., Dörfler, V. and Nudurupati, S.S. (2012), “Performance measurement: challenges for tomorrow”, *International Journal of Management Reviews*, Vol. 14 No. 3, pp. 305-327.

Bourne, M., Franco-Santos, M., Micheli, P. and Pavlov, A. (2018a), “Performance measurement and management: a system of systems perspective”, *International Journal of Production Research*, Vol. 56 No. 8, pp. 2788-2799.

Bourne, M., Kinnerley, M. and Franco-Santos, M. (2005), “Managing through measures: a study of impact on performance”, *Journal of Manufacturing Technology Management*, Vol. 16 No. 4, pp. 373-395.

Bourne, M., Melnyk, S. and Bititci, U. (2018b), “Performance measurement and management: theory and practice”, *International Journal of Operations & Production Management*, Vol. 38 No. 11, pp. 2010-2021.

Bourne, M., Mills, J., Wilcox, M., Neely, A. and Platts, K. (2000), “Designing, implementing and updating performance measurement systems”, *International Journal of Operations & Production Management*, Vol. 20 No. 7, pp. 754-771.

Cappelli, P. (2020), “Stop Overengineering People Management - The trend toward optimization is disempowering employees”, *Harvard Business Review*, Vol. 98 No. 5, pp. 56-63.

Davenport, T.H. (2006), “Competing on analytics”, *Harvard Business Review*, Vol. 84 No. 1, pp. 98-107.

Dechow, N. and Mouritsen, J. (2005), “Enterprise resource planning systems, management control and the quest for integration”, *Accounting, Organizations and Society*, Vol. 30 No. 7-8, pp. 691-733.

de Treville, S. and Antonakis, J. (2006), “Could lean production job design be intrinsically motivating? Contextual, configurational, and levels-of-analysis issues”, *Journal of Operations Management*, Vol. 24 No. 2, pp. 99-123.

Eccles, R.G. (1991), “The performance measurement manifesto”, *Harvard Business Review*, Vol. 69 No. 1, pp. 131-137.

Ferreira, A. and Otley, D. (2009), “The design and use of performance management systems: an extended framework for analysis”, *Management Accounting Research*, Vol. 20 No. 4, pp. 263-282.
Floyd, S.W. and Wooldridge, B. (1994), “Dinosaurs or dynamos: recognizing middle management’s strategic role”, *Academy of Management Executive*, Vol. 8 No. 4, pp. 47-57.
Frank, A.G., Dalenogare, L.S. and Ayala, N.F. (2019), “Industry 4.0 technologies: Implementation patterns in manufacturing companies”, *International Journal of Production Economics*, Vol. 210, pp. 15-26.
Garengo, P., Nudurupati, S.S. and Bititci, U. (2007), “Understanding the relationship between PMS and MIS in SMEs: an organizational life cycle perspective”, *Computers in Industry*, Vol. 58 No. 7, pp. 677-686.
Hall, M. (2008), “The effect of comprehensive performance measurement systems on role clarity, psychological empowerment and managerial performance”, *Accounting, Organizations and Society*, Vol. 33 No. 2-3, pp. 141-163.
Hamel, G. (2009), “Moon shots for management”, *Harvard Business Review*, Vol. 87 No. 2, pp. 91-98.
Hekneby, T., Ingvaldsen, J.A. and Benders, J. (2020), “Managing adoption by cultural development: exploring the plant level effect of a ‘company specific production system’ (XPS) in a Norwegian multinational company”, *Journal of Industrial Engineering and Management*, Vol. 13 No. 2, pp. 402-416.
Hermkens, F.J.A., Romme, A.G.L. and Dolmans, S.A.M. (2020), “An exploratory study of middle manager’s roles in continuous improvement”, *International Business Research*, Vol. 13 No. 5, pp. 9-30.
Hirzel, A.-K., Leyer, M. and Moormann, J. (2017), “The role of employee empowerment in the implementation of continuous improvement”, *International Journal of Operations & Production Management*, Vol. 37 No. 10, pp. 1563-1579.
Holmemo, M.D.Q. and Ingvaldsen, J.A. (2016), “Bypassing the dinosaurs? How middle managers become the missing link in lean implementation”, *Total Quality Management & Business Excellence*, Vol. 27 No. 11-12, pp. 1332-1345.
Ingvaldsen, J.A. and Benders, J. (2016), “Lost in translation? The role of supervisors in lean production”, *German Journal of Human Resource Management: Zeitschrift für Personalforschung*, Vol. 30 No. 1, pp. 35-52.
Ingvaldsen, J.A. and Benders, J. (2020), “Back through the back door? On removing supervisors to reduce hierarchy”, *Baltic Journal of Management*, Vol. 15 No. 3, pp. 473-491.
Jääskeläinen, A. and Luukkanen, N. (2017), “The use of performance measurement information in the work of middle managers”, *International Journal of Productivity and Performance Management*, Vol. 66 No. 4, pp. 479-499.
Jardioui, M., Garengo, P. and El Alami, S. (2019), “How organizational culture influences performance measurement systems in SMEs”, *International Journal of Productivity and Performance Management*, Vol. 69 No. 2, pp. 217-235.
Kamble, S.S., Gunasekaran, A., Ghadge, A. and Raut, R. (2020), “A performance measurement system for industry 4.0 enabled smart manufacturing system in SMMEs- A review and empirical investigation", *International Journal of Production Economics*, Vol. 229, pp. 1-15, doi: 10.1016/j.ijpe.2020.107853

Kaplan, R.S. and Norton, D.P. (1992), "The balanced scorecard—Measures that drive performance", *Harvard Business Review*, Vol. 70 No. 1**,** pp. 71-79.

Kirkman, B.L. and Rosen, B. (1999), "Beyond self-management: antecedents and consequences of team empowerment", *Academy of Management Journal*, Vol. 42 No. 1, pp. 58-74.

Kolehmainen, K. (2010), "Dynamic strategic performance measurement systems: balancing empowerment and alignment", *Long Range Planning*, Vol. 43 No. 4, pp. 527-554.

Lebas, M. (1995), "Performance measurement and performance management", *International Journal of Production Economics*, Vol. 41 No.1-3, pp. 23-35.

Lewis, R.L., Brown, D.A. and Sutton, N.C. (2019), "Control and empowerment as an organising paradox: implications for management control systems", *Accounting, Auditing & Accountability Journal*, Vol. 32 No. 2, pp. 483-507.

Leyer, M., Richter, A. and Steinhüser, M. (2019), "Power to the workers", *International Journal of Operations & Production Management*, Vol. 39 No. 1, pp. 24-42.

Marchand, M. and Raymond, L. (2008), "Researching performance measurement systems", *International Journal of Operations & Production Management*, Vol. 28 No. 7, pp. 663-686.

Melnyk, S.A., Bititci, U., Platts, K., Tobias, J. and Andersen, B. (2014), "Is performance measurement and management fit for the future?", *Management Accounting Research*, Vol. 25 No. 2, pp. 173-186.

Neely, A., Gregory, M. and Platts, K. (1995), "Performance measurement system design: a literature review and research agenda", *International Journal of Operations & Production Management*, Vol. 15 No. 4, pp. 80-116.

Neely, A., Mills, J., Platts, K., Richards, H., Gregory, M., Bourne, M. and Kennerley, M. (2000), "Performance measurement system design: developing and testing a process-based approach", *International Journal of Operations & Production Management*, Vol. 20 No. 10, pp. 1119-1145.

Nonaka, I. (1994), "A dynamic theory of organizational knowledge creation", *Organization Science*, Vol. 4 No. 1, pp. 14-37.

Nudurupati, S.S. and Bititci, U. (2005), "Implementation and impact of IT-supported performance measurement systems", *Production Planning & Control*, Vol. 16 No. 2, pp. 152-162.

Nudurupati, S.S., Bititci, U., Kumar, V. and Chan, F.T.S. (2011), "State of the art literature review on performance measurement", *Computers & Industrial Engineering*, Vol. 60 No. 2, pp. 279-290.

Otley, D. (1999), "Performance management: a framework for management control systems research", *Management Accounting Research*, Vol. 10 No. 4, pp. 363-382.

Peters, M.D., Wieder, B., Sutton, S.G. and Wakefield, J. (2016), "Business intelligence systems use in performance measurement capabilities: implications for enhanced competitive advantage", *International Journal of Accounting Information Systems*, Vol. 21, pp. 1-17.

Psoinos, A., Kern, T. and Smithson, S. (2000), "An exploratory study of information systems in support of employee empowerment", *Journal of Information Technology*, Vol. 15 No. 3, pp. 211-230.

Raffoni, A., Visani, F., Bartolini, M. and Silvi, R. (2017), "Business performance analytics: exploring the potential for performance management systems", *Production Planning & Control*, Vol. 29 No. 1, pp. 51-67.

Ren, L., Zhang, L., Wang, L., Tao, F. and Chai, X. (2014), "Cloud manufacturing: key characteristics and applications", *International Journal of Computer Integrated Manufacturing*, Vol. 30 No. 6, pp. 501-515.

Rikhardsson, P. and Yigitbasioglu, O. (2018), "Business intelligence and analytics in management accounting research: status and future focus", *International Journal of Accounting Information Systems*, Vol. 29, pp. 37-58.

Robert, M., Giuliani, P. and Gurau, C. (2020), "Implementing industry 4.0 real-time performance management systems: the case of Schneider Electric", *Production Planning &* Control, Vol. ahead-of-print No. ahead-of print. doi: 10.1080/09537287.2020.1810761

Safisadeh, M.H., Ritzman, L.P., Sharma, D. and Wood, C. (1996), "An empirical analysis of the product-process matrix", *Management Science*, Vol. 42 No. 11, pp. 1576-1591.

Sardi, A., Garengo, P. and Bititci, U. (2019), "Measurement and management of competences by enterprise social networking", *International Journal of Productivity and Performance Management*, Vol. 68 No. 1, pp. 109-126.

Sardi, A., Sorano, E., Cantino, V. and Garengo, P. (2020a), "Big data and performance measurement research: trends, evolution and future opportunities", *Measuring Business Excellence*, Vol. ahead-of-print No. ahead-of-print. doi: 10.1108/MBE-06-2019-0053

Sardi, A., Sorano, E., Ferraris, A. and Garengo, P. (2020b), "Evolutionary paths of performance measurement and management system: the longitudinal case study of a leading SME", *Measuring Business Excellence*, Vol. 24 No. 4, pp. 495-510.

Schwarzmüller, T., Brosi, P., Duman, D. and Welpe, I.M. (2018), "How does the digital transformation affect organizations? Key themes of change in work design and leadership", *Management Revue*, Vol. 29 No. 2, pp. 114-138.

Smith, M. and Bititci, U. (2017), "Interplay between performance measurement and management, employee engagement and performance", *International Journal of Operations & Production Management*, Vol. 37 No. 9, pp. 1207-1228.

Spreitzer, G.M. (1995), "Psychological empowerment in the workplace: dimensions, measurement, and validation", *Academy of Management Journal*, Vol. 38 No. 5, pp. 1442-1465.

Spreitzer, G.M. (1996), "Social structural characteristics of psychological empowerment", *Academy of Management Journal*, Vol. 39 No. 2, pp. 483-504.

Thomas, K.W. and Velthouse, B.A. (1990), "Cognitive elements of empowerment: an 'interpretive' model of intrinsic task motivation", *Academy of Management Review*, Vol. 15 No. 4, pp. 666-681.

Torres, R., Sidorova, A. and Jones, M.C. (2018), "Enabling firm performance through business intelligence and analytics: a dynamic capabilities perspective", *Information & Management*, Vol. 55 No. 7, pp. 822-839.

Trotta, D. and Garengo, P. (2019), "Assessing Industry 4.0 maturity: an essential scale for SMEs", 8th International Conference on Industrial Technology and Management (ICITM), IEEE, pp. 69-74

Vallurupalli, V. and Bose, I. (2018), “Business intelligence for performance measurement: a case based analysis”, *Decision Support Systems*, Vol. 111, pp. 72-85.

Wilkinson, A. (1997), “Empowerment: theory and practice”, *Personnel Review*, Vol. 27 No. 1, pp. 40-56.

Wooldridge, B., Schmid, T. and Floyd, S.W. (2008), “The middle management perspective on strategy process: contributions, synthesis, and future research”, *Journal of Management*, Vol. 34 No. 6, pp. 1190-1221.

Yin, R.K. (2014), *Case Study Research: Design and Methods*, SAGE, Los Angeles.

Digital technologies and the balance between control and empowerment in performance management

Eirik B. Hamre Korsen
Assistant Professor/PhD candidate, Norwegian University of Science and Technology

Marte Daae-Qvale Holmemo
Associate Professor, Norwegian University of Science and Technology

Jonas A. Ingvaldsen
Professor, Norwegian University of Science and Technology

A reviewed version of this article was published in *Measuring Business Excellence* on 30. December 2021.
https://doi.org/10.1108/MBE-04-2021-0055

Abstract

Purpose – This paper explores how manufacturing organisations' performance measurement and management (PMM) systems are evolving when digital technologies (DTs) are deployed. It focuses on the operational level, asking whether DTs are used to promote command-and-control or empowerment-oriented performance management.

Design/methodology/approach – The findings are based on a single case study from a department of a Norwegian electrochemical plant. The department recently implemented a performance measurement system (PMS) supported by DTs to capture, analyse, and visualise close-to-real-time performance data on individuals and teams. We analysed both the management practices associated with the new PMS, and how those related to other PMM-subsystems in the organisation.

Findings – When seen in isolation, the new PMS was used to promote empowerment, and operators reported a significant increase in perceived psychological empowerment. However, other parts of the organisation's PMM system remained control-oriented, so that the overall balance between control and empowerment remained stable.

Practical implications – New PMSs might be added to support local needs and create arenas for empowerment without disturbing the overall balance in the PMM system.

Originality/value – Building on the insights from the case study, we propose that DTs may be deployed to promote both command-and-control and empowerment within different PMM subsystems in the same organisation. Hence, the deployment of DTs is likely to have contradictory effects, which is best understood through a "system of systems" perspective on PMMs.

Keywords: performance measurement, performance management, empowerment, digital technology, system of systems

Paper type Research paper

Acknowledgements
The research is funded by The Research Council of Norway.

Introduction

Performance measurement and management (PMM) systems that balance control and empowerment are fundamental to the management of organisations (Bititci *et al.*, 2012; Franco-Santos *et al.*, 2012). A vital component of any PMM system is the information technology (IT) that supports the collection, analysis, reporting, and presentation of performance information (Bititci *et al.*, 2012).

Trends of digitalisation and industry 4.0, including the Internet of Things, cloud manufacturing, big data, business analytics, and artificial intelligence, have the potential to radically change the way we manage (Cappelli, 2020; Frank *et al.*, 2019; Robert *et al.*, 2020; Sardi *et al.*, 2020a). Digital technologies (DT) combine information, communication, computing, and connectivity technologies (Bharadwai *et al.* 2013), extending earlier IT with innumerable and dispersed information (Hanelt *et al.*, 2021). DT enable more frequent and detailed performance measures through automatic and real-time data collection, analysis, and reporting (Sardi *et al.*, 2019; Sardi *et al.*, 2020a). However, what effects these technologies have on performance management practices are still uncertain, and empirical research has documented diverse developments (Robert *et al.*, 2020; Sardi *et al.*, 2020b; Smith and Bititci, 2017). On the one hand, the sharing of rich performance data can be an enabler for empowerment (Bititci, 2015; Bititci *et al.*, 2018; Melnyk *et al.*, 2014; Neely *et al.*, 2000). On the other hand, the extensive use of DTs might overengineer people management, leading to disempowerment and more command-and-control (Bailey and Barley, 2020; Cappelli, 2020). It remains a basic insight that new technology itself does not determine the magnitude or direction of changes; organisations make choices about what purpose the technology is supposed to serve (Bailey and Barley, 2020). However, our understanding of which factors are considered, along with how technology deployment is used as an occasion to either reinforce or readjust practices of performance management, remains undeveloped. Based on this background, the paper asks:

> *How is the balance between command-and-control and empowerment in PMM systems altered when organisations deploy digital technologies?*

In order to answer this research question, a single department from an electrochemical plant was purposively selected for in-depth investigations. The department had recently implemented what they called "Team Performance", a PMS using DTs to automatically capture and report fine-grained performance data on individual operators, which are then to be reviewed within the team. Hence, it is a typical example of contemporary digital change.

Our main finding is that although Team Performance promoted empowerment in quite a radical way, its impact on the overall PMM system was modest and localised to one particular subsystem of performance management. Other subsystems that reflected the logic of command-and-control remained intact, and were supported by their own IT solution. This finding clearly suggests conceptualising a PMM system as a "system of systems" (Bourne *et al.* 2018) when analysing the impact of DTs. Although DTs may sometimes lead to a system-wide change toward either more command-and-control or empowerment (e.g., Sardi *et al.* 2020b), we propose that the more likely development in most organizations is that DTs are deployed within subsystems to support diverse – possibly contradictory and loosely coupled – performance management practices. Hence, the short-term effect of DT deployment is likely to reproduce rather than challenge the existing balance between command-and-control and empowerment in organisations.

Theoretically, the article contributes by showing how a combination of Smith and Bititci´s (2017) PMM framework and Bourne *et al.*'s (2018) system of systems perspective may advance our understanding of how DT deployment impacts PMM. As the main implication for practice, we suggest that PMM subsystems might be added to support local needs and promote empowerment without disturbing the overall balance in the PMM system. Even modest changes can have a positive effect on the perceived (psychological) empowerment (Lewis *et al.*, 2019).

PMM and DTs

The PMM literature has evolved from a focus on how to design and implement a balanced set of performance measures (Bourne *et al.* 2000; Kaplan and Norton, 1993) toward emphasis on how the measures are used to manage performance (Bititci *et al.*, 2012; Melnyk *et al.*, 2014; Tessier and Otley, 2012). Smith and Bititci (2017) suggested an influential framework that is grounded in organisational control theory, where the performance measurement system (PMS) and performance management practices are recognised as two separate, yet interrelated, dimensions of PMM. With the help of this framework, an organisation's PMM systems can be represented as coordinates in two-dimensional space.

PMS is defined as the process (or processes) to set targets, collect, analyse, evaluate, and act upon performance data (Bititci, 2015; Melnyk *et al.*, 2014). In the framework, it is described according to a maturity scale, where a mature PMS has a balanced set of measures that are linked to the strategy and used across organisational levels for frequent reviews. The performance management dimension in Smith and Bititci's (2017) framework is "[s]een as a continuum of practice that spans from command and control to democratic and participative management" (p. 1210). A command-and-control management style is directive, emphasises tight control of standardised tasks, promotes internal competition, and rewards performance. A democratic and participative management style is empowering, and it encourages job enrichment, autonomy, and participation, where intrinsic motivation is thought to drive performance (Bititci, 2015; Smith and Bititci, 2017).

Current trends of digitalisation and industry 4.0, such as the Internet of Things, cloud manufacturing, big data, business analytics, and artificial intelligence, enable automatic and real-time data collection, analysis, and visualisations (Frank *et al.*, 2019; Kamble *et al.*, 2020; Robert *et al.*, 2020; Sardi *et al.*, 2020a; Trotta and Garengo, 2019). The deployment of these technologies has been modelled as interventions in the PMM system, which induce organisations to find a new position (a new balance) in the Smith and Bititci two-dimensional space (Nudurupati *et al.*, 2020; Sardi *et al.*, 2019; Sardi *et al.*, 2020b). As illustrated in Figure 1, there is consensus that DTs increase the maturity of the PMS. However, results have been mixed on how these technologies interact with the performance management practices. The evolutionary path has been found to move toward both directive command-and-control and empowerment, subject to a range of contingency factors (Nudurupati *et al.*, 2020; Raffoni *et al.*, 2017; Sardi *et al.*, 2019; Sardi *et al.*, 2020b; Vallurupalli and Bose, 2018).

A system-of-systems perspective

Although describing organizations in a two-dimensional space is a convenient simplification for both theoretical and practical purposes (Bititci, 2015), it has limitations when assessing the impact of ICT deployment. Most importantly, both performance measurement and performance management are portrayed as unitary; therefore, the internal diversity and contradictory nature of actual PMM systems are concealed (Franco-Santos *et al.*, 2007; Malmi and Brown, 2008). For example, many organisations combine different schemes for employee suggestions and participation (i.e., empowerment) with tight financial controls and strict rule-based safety management (i.e., command-and-control). Under the assumption of unitary PMM systems, DT deployment is thought to push the overall system *either* toward more command-and-control *or* toward more empowerment. Furthermore, the impact of new technology is easily overstated when DT-induced changes in parts of the PMM system (available for investigation) are thought to be indicative of developments at the overall system level.

One way to develop a more nuanced understanding of the impact of DT deployment is to follow Bourne *et al.*'s (2018) suggestion to view a PMM system not as unitary but rather as a "system of systems" that is "bundled together to produce a multitude of responses that can help decision makers navigate through the complexity and make progress" (Bourne *et al.*, 2018, p. 2790). Within this perspective, the subsystems are allowed to be diverse in technology and in context, serve different purposes, and be loosely coupled to other subsystems (Bourne *et al.*, 2018). For example, applications of business intelligence or artificial intelligence can be designed to serve local needs independently of other PMM subsystems. Over time, organisations accumulate a portfolio of specialised subsystems in which old IT, DTs, and manual routines for PMM coexist.

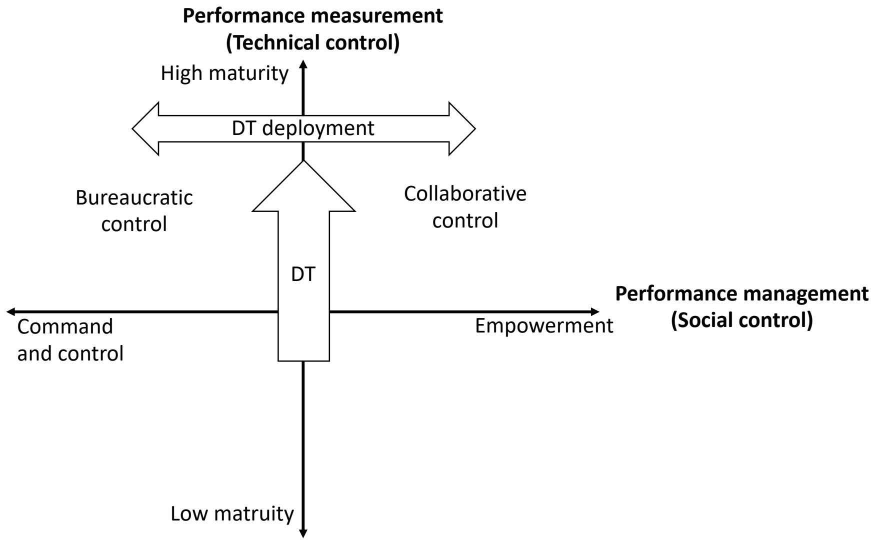

Figure 1. Illustration of how DTs interact with performance measurement and performance management based on Smith and Bititci's (2017) framework.

Methodology

Selection and context of the case

In order to gain in-depth insights on how the deployment of DTs impacts the PMM system, a single-case organisation was purposively sampled (Yin, 2014). A department at an electrochemical plant (referred to as DEP throughout the paper) was identified as the unit of analysis. The department has around 240 employees, and it is divided into five shifts, with seven teams on each shift. The department's product, liquid light-metal, is made in large batches and sent to a casthouse for further processing. Production is continuous and around the clock.

Light-metal products are traded on a global market. History shows that market prices and demand fluctuate, and at times (e.g., during the financial crisis in 2008), the plant experienced challenges that resulted in a reduction of production capacity. Thus, a focus on costs and efficiency becomes essential in order to secure jobs and part of the license to operate. Located in rural Norway, the plant is the cornerstone of the local community.

Data collection and analysis

Data were collected by two researchers (the first and second author of this paper) during a two-day visit to the plant in October 2020. The researchers conducted seven observations on the factory floor, along with seven observations of meetings, and had one-to-one conversations with 15 informants, of which five were structured as in-depth interviews. Following the plant visit, 10 additional in-depth interviews were conducted through MS Teams with informants from all organisational levels: operators, employee representatives, middle managers (shift managers and process managers), the division manager, and divisional support staff, including the head of organisation development and the project manager with the responsibility of designing the overall PMS. In addition, the researchers had obtained secondary data from collaborating with the case organisations over several years, including visits to other plants, participation in workshops, and other activities.

Field notes and transcribed interviews were analysed by both researchers, and discussed to develop common interpretations. The data were analysed in two steps. In the first step, Team Performance was analysed based on Smith and Bititci's (2017) PMM framework, with emphasis on PMS characteristics and the related performance management practices. During the first analysis, it became clear that Team Performance was only one out of several PMSs that the workers and managers related to in their daily work. Based on this insight, a second analysis was performed based on Bourne *et al.'s* (2018) system of systems perspective. In this step, we identified additional subsystems working in parallel with Team Performance, and described those along Smith and Bititci's (2017) dimensions (see Table 1). We analysed the additional PMSs of standard operating procedures (SOP), walk–observe–communicate (WOC), the health, environment, and safety (HES) policy, the deviation reporting system, and performance reviews. Although other subsystems also existed, such as budgets and audits, these were less frequently mentioned, and they seemed to have had less of an impact on the daily work of our informants. In a final step to validate our findings, a summary of the analysis was presented to managers in the organisation, who confirmed that it made good sense as a description of Team Performance and the wider PMM system at DEP.

Findings

Team Performance and the use performance data

Based on observations and interviews, we classified Team Performance as a mature PMS; it captured, stored, analysed, and reported on performance indicators from multiple sources close to real-time. Reports with a traffic-light visualisation of actual performance compared to defined targets were updated daily and made easily accessible to operators on large screens in common rooms. There was a formal process for reviewing performance on a five-week cycle, where middle managers and operators discussed the performance to identify potential improvements.

Continuous improvement is the main priority at DEP, and Team Performance was developed to serve that end. The DT intervention was the combination of implementing a wireless network on the factory floor, along with sensors and business intelligence technology. This enabled a systematic, frequent, and highly granulated collection of operational data, which was the basis for defining performance indicators that explain the causal effects between operational tasks and performance.

Along the performance management dimension, Team Performance promoted empowerment. Team Performance intended to provide fact-based and precise feedback to the teams and the operators on their performance based on the idea that frequent feedback would motivate the operators to improve their own performance.

> *The basic philosophy is that people should see the link between their actions and the overall performance of the firm. (...) This is no surveillance system, it's a feedback system. (Head of organisation development)*

Both the interviews and the observations of the performance review meetings indicated that there was a common understanding between managers and operators that Team Performance was the "operators' PMS", and that the middle managers' role was facilitative. This was explained by one of the shift managers as follows:

> *My role is to nudge, request and supervise the teams' TP processes and agendas. (...) We are not fond of too many long meetings, but three minutes at the beginning and end of the working day when we are gathered anyway works for us. I try to attend if I have the opportunity, [...] but now it is working on its own, so my role is minimal compared to the team manager. (Shift manager)*

We identified how the frequent and fine-grained performance data in Team Performance were only used in a formative and interactive way, and in a dialog where operators had influence over their own work and participated in improvements. There was also a formal agreement between management and union representatives on how Team Performance with performance data on teams and individuals could only be used for learning, training, and improvements.

> *When HR were to update the agreement protocol with the union, this only took five minutes. The union said all reports [from members concerning TP] were positive. (HR manager)*

Team Performance as one of several subsystems

Throughout the investigations, informants frequently referred to other PMSs besides Team Performance. Inspired by Bourne *et al.*'s (2018) idea of PMM as a system of systems, we mapped the frequently mentioned subsystems onto Smith and Bititici's (2017) space (see Figure 2). In Table 1, the relevant subsystems are described along the framework's dimensions.

The subsystems are connected to each other through a structure of formal meetings, from daily operational meetings between shifts to monthly or quarterly management reviews. We interpret this structure of meetings not to be a distinct subsystem but rather an integrating routine.

Together, the subsystems combined control and compliance in a command-and-control fashion, with empowerment in which feedback, involvement, and learning were emphasised. DEP (and the company they are part of) did not have a unitary, balanced PMM system; rather, the balance emerged in the combination and interaction of several subsystems. Correspondingly, their IT portfolio was diverse, and one subsystem even made no use of IT (i.e., WOC). The relatively loose couplings meant that new systems supported by DT could be added (or removed) and older systems could be upgraded with new technology without triggering much integration effort. By adding Team

Performance, the organisation created a new arena for empowerment, yet the overall balance between control and empowerment remained stable. Still, as we observed, the relatively small change with Team Performance had a positive effect on the perceived psychological empowerment (Hall, 2008; Lewis *et al.*, 2019).

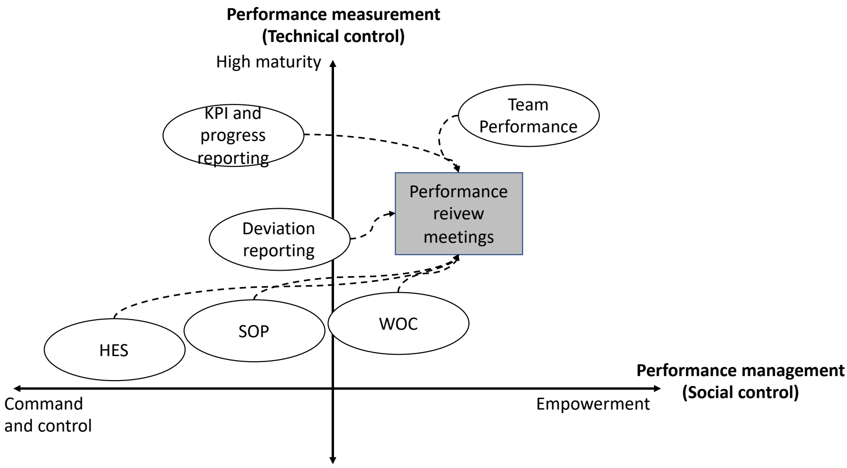

Figure 2: Subsystems in DEP described along Smith and Bititici´s (2017) dimensions. Abbreviations: HES – health, environment, and safety, SOP – standard operating procedures, WOC – walk–observe–communicate.

Table I: PMM as subsystems

Subsystem	PMS characteristics, including DT/IT support	Performance management practice	Illustrative examples (observation, interviews)
Team Performance	• Semi-automatic collection and reporting of measures in a central database • Visualisation of performance on teams and individuals (pseudonyms) • Access to historical data and other teams' performance • Targets set on DEP level by consensus within shifts • Formal meeting for each shift every five weeks • No rewards or punishments are connected to performance	• Teams monitor performance on screens at the beginning of each shift and during breaks • Informal discussions concerning performance scores and specific focus areas • Operators read measures on their own performance by their individual pseudonyms (even if the pseudonyms is known to all members within the team), and can compare themselves to others • Formal meetings in teams where shift managers and process managers participate, discuss results, and identify focus areas • Process manager has a supporting role in data analysis and problem solving • Teams suggest improvements of the PMS to the process manager (e.g., new key performance indicators (KPIs) and changes in target values)	• "TP [Team Performance] is a pretty good tool for repetitive tasks. You could fall into auto pilot doing the same things every day (…) TP gives us statistics which we can use to discuss how to improve our results" (Operator, team responsible) • "We never use it [performance results] against people; we use it for helping everyone (…) We rather analyse cases of good results and consider what we can implement in the SOPs" (Process manager)

SOP	• Detailed process description with "best practices" for executing work • Used as a reference guide for operators' daily work and a basic training document for new employees • Standard format with local content • Formal procedures to make changes in the SOP based on scientific approaches, including version control and approvals • SOP details include one-point lessons and 5S (a lean-tool) documentation • Stored in a central database, and available in a Web format	• An SOP is developed in collaboration between operators, one or two from each shift, and is facilitated by process managers • Operators are expected to loyally follow instructions in the SOP. Although detailed, operators discuss how different interpretations across teams cause different performance scores • Improvement in SOP is initiated based on issues discovered in Team Performance, WOC, quality assessments, and audits • Changes to the SOP follow a separate process, and are formally approved by the local department manager	• "We have had SOPs for years (…) There is room for interpretation. There are no instructions to put your right foot in front of the left. (…) We used to have private notebooks where all the secret details were written (…) Now, we have arenas for team discussions [i.e., Team Performance meetings]." (HR manager)

HES	• Detailed description of safety requirements for personnel and equipment, including equipment and procedures for risk assessment • Deviations and incidents are reported in the deviation system and reviewed systematically at all levels of the organisation	• All employees, vendors, and visitors are briefed and trained (digital app) in safety procedures before entering the factory • All performance meetings start with HES reviews • Minor deviations or incidents are followed up locally to improve compliance • No formal punishment for deviations • Larger incidents are reported and addressed	• Observation: An employee reported a deviation regarding a colleagues' protective gear. This deviation was referred to during a shift meeting, without naming the employee, and all employees were reminded to put on their protective gear before starting their shift

WOC	• Managerial weekly procedure • A manager visits the factory floor to observe and control the quality of work, and communicate feed-back to operators • Each employee (including all managers) has responsibility for the quality (following 5S, HES) of one or more workstations • Deviations (SOP, 5S, HES) are discussed and registered in the deviation reporting system • Managers register reports that WOC is completed	• All managers on all levels in DEP attend WOC and are dressed and equipped as operators (HES approved) • Some managers document all deviations formally, while others actively correct workstations in collaboration with the responsible employee • The team manager controls the middle managers' assigned workstations in the same manner • Formal routines are observed, yet communication is informal and gentle • Managers reflect upon the status and important issues from WOC in management meetings	• "This is a regime that captures what's in between measures. It is an essential procedure to observe and give feedback to the individual worker, to be able to build competence over time." (Process manager B) • "[It's how we practice] the principle of visual management where the managers support and prioritize areas by walking around out there, being interested, and showing this is fun." (HR manager)

Deviation reporting	• Manual reporting of deviation from HES policy, SOP, or 5S equipment faults and unexpected incidents • Deviations are allocated to a responsible person, including risk and intervention. A case is not closed until a solution has been reported • The number of deviations and the status are reported in performance reviews • All managers and employees have access to register • A central database is accessible through a Web interface for both entering deviations and reading reports	• Deviation from the last 24 hours is displayed and noted at the beginning of each shift • Managers show reports in meetings to identify errors, deviations, and problems • Focus on systemic weaknesses, not individual errors • Deviation reporting is promoted by management • Deviations from HES policy are handled more formally than are deviations from 5S or SOPs	• Observation: A deviation report, including HES issues and equipment failures, was briefly reviewed in each shift meeting. Larger deviations requiring reinvestment or maintenance were discussed in management meetings

KPI and progress reporting	• A management tool to get an overview and prioritise any corrective actions for unsatisfactory performance • A digital scorecard with performance indicators for core processes • A progress report on improvement initiatives • Regular meetings with various frequencies, attendance (roles and levels), and standard forms. Daily shift meetings, and weekly, bi-weekly, monthly, or quarterly performance reviews on different levels • Data collected on a number of systems. Reported monthly in Excel/PowerPoint	• Monitored and discussed in regular meetings where content and frequency match operational cycles and governance structure • Discussions are structured with a focus on facts and data, along with improvement areas and solutions • Although there are clear roles and authorities, openness for disagreements/debates concern the matter, not the person	• "The team's responsible operator owns the TP-meeting. It's about their five-week effort. I check the A3s [the documentation], assignments, and check performance according to targets, and if there is improvement or not. Based on this, I can pose relevant questions during the meeting." (Process manager A)

Discussion

The analysis of Team Performance in isolation corroborates previous findings on DT deployment and PMM. Influenced by the existing organisational culture and management practices, a more mature PMS was used to promote empowerment through feedback and learning (Nudurupati *et al.*, 2020; Sardi *et al.*, 2019; Sardi *et al.*, 2020b). However, by zooming out on the overall PMM system, we noticed that Team Performance only applied to some of the operators' tasks. Other tasks were governed by other PMM subsystems. Hence, the overall balance between command-and-control and empowerment in the organisation remained stable.

To our knowledge, this paper is the first to respond to Bourne *et al.*'s (2018, p. 2796) suggestion to combine the system of systems perspective with Smith and Bititci's (2017) PMM framework. Doing this allows for a more nuanced treatment of technology deployment when applying the framework. Importantly, the system of systems perspective implies that DT may be deployed in order to promote both command-and-control and empowerment within different PMM subsystems in the same organisation. Even if changes toward an empowering PMM system are desirable (Nudurupati *et al.* 2020), the emerging practices are influenced by existing subsystems, which can be more or less mature and more or less directive in nature. We expect that tightly coupled PMM systems are the more constraining environments for DT deployment because of the requirements for both technology integration and organizational alignment. Conversely, more loosely coupled systems might allow for greater diversity in terms of both technology and practices.

Replacing system-wide solutions tends to be costly and is associated with significant technological risk, as demonstrated in literature on enterprise resource planning (e.g., Benders *et al.*, 2006). Furthermore, research on organizational behaviour has documented that organisations tend to deal with issues in a sequential and piecemeal fashion, even when the issues are mutually interdependent (Gavetti *et al.*, 2012). Therefore, even though it might mean forgoing opportunities for radical improvements, we expect organisations to approach the deployment of DT in an incremental fashion.

Our main argument gives reason to question the widely held notion that DTs and Industry 4.0 will bring about radical workplace change (e.g., Gupta *et al.*, 2020), at least with respect to PMM. Hiding behind the labels "digital technologies" and "Industry 4.0" is a wide range of solutions that can – and will be – put to different uses within different subsystems. When each subsystem is digitally reinforced, it is likely to create an overall balance in the system.

This paper has demonstrated the value of applying systems thinking in order to understand technological changes in PMM systems, yet many further steps can be taken to formalise the insights into a testable and applicable theory. Since systems thinking is found across many engineering and social science disciplines, PMM may borrow ideas from related fields, as was done by Bourne *et al.* (2018). For example, concepts and models to describe the interrelatedness between subsystems and dynamics of change can be adopted from organization design theory (e.g., Achterbergh and Vriens, 2010). From applied systems thinking (e.g., Flood, 2010), we can learn how to model and support digital transformations and promote PMM systems with a desirable balance between control and empowerment.

Limitations
One limitation of this study pertains to how the findings from a case study are influenced by a specific context (Yin, 2014). A comparable case study where a command-and-control management style is dominant would be interesting to contrast to the findings. The study is also based on a snapshot of the current use of the PMM systems in the organisation. Longitudinal studies are necessary to understand how subsystems interrelate and evolve over time, which practices become institutionalised, and which are discarded (Cloutier and Langley, 2020).

Conclusions and practical implications

Deploying DTs improves the maturity of the PMS. However, the effects on performance management practices depend on which subsystem is subject to intervention, and how this subsystem is coupled to other PMM subsystems. A system-wide change can indeed be brought about, yet we expect most organizations to mature their PMM system in a more incremental, piecemeal fashion, thus preserving the overall balance between command and control and empowerment.

An incremental strategy to deploy DTs may also be advantageous in practice. A system of systems perspective recognizes that one size *does not* fit all. To create a robust IT architecture, organisations may recognise that different tools serve different purposes. The combination of mandatory enterprise-wide systems and a collection of smaller, optional, and customised systems might fulfil the organisation's PMM needs. For example, we have seen how Team Performance fits well in the context of measurement-driven management (Melnyk *et al.* 2014), where both the input and the output of the process is well-understood. In other parts of the organisation, where the process is exposed to greater uncertainty and ambiguity, other management approaches and other kinds of DT support are likely required. In this way, new custom-made arenas for empowerment might be added, with positive effects for employee motivation and continuous improvement. Furthermore, with an incremental approach new technologies may be tested and implemented via local prototyping. This has the obvious advantage of reducing the risks related to DT investment compared to larger and more holistic approaches.

References

Achterbergh, J. and Vriens, D. (2010), *Organizations: Social Systems Conducting Experiments*, Springer Verlag, Heidelberg.

Bailey, D.E. and Barley, S.R. (2020), “Beyond design and use: how scholars should study intelligent technologies”, *Information and Organization*, Vol. 30 No. 2, pp.1-12.

Benders, J., Batenburg, R. and van der Blonk, H. (2006), “Sticking to standards; technical and other isomorphic pressures in deploying ERP-systems”, *Information & Management*, Vol. 43 No. 2, pp.194-203.

Bharadwai, A., El Sawy, O.A., Pavlou, P.A. and Venkatraman, N. (2013), “Digital buiness strategy: toward a next generation of insights”, *MIS Quarterly*, Vol. 37 No. 2, pp.471-482.

Bititci, U. (2015), *Managing business performance, the science and the art*, John Wiley & Sons, Chichester.

Bititci, U., Bourne, M., Farris Cross, J.A., Nudurupati, S.S. and Sang, K. (2018), “Editorial: towards a theoretical foundation for performance measurement and management”, *International Journal of Management Reviews*, Vol. 20 No. 3, pp.653-660.

Bititci, U., Garengo, P., Dörfler, V. and Nudurupati, S.S. (2012), “Performance measurement: challenges for tomorrow”, *International Journal of Management Reviews*, Vol. 14 No. 3, pp.305-327.

Bourne, M., Franco-Santos, M., Micheli, P. and Pavlov, A. (2018), “Performance measurement and management: a system of systems perspective”, *International Journal of Production Research*, Vol. 56 No. 8, pp.2788-2799.

Bourne, M., Mills, J., Wilcox, M., Neely, A. and Platts, K. (2000), “Designing, implementing and updating performance measurement systems”, *International Journal of Operations & Production Management*, Vol. 20 No. 7, pp.754-771.

Cappelli, P. (2020), “Stop overengineering people management – the trend toward optimization is disempowering employees”, *Harvard Business Review*, Vol. 98 No. 5, pp.56-63.

Cloutier, C. and Langley, A. (2020), “What makes a process theoretical contribution?”, *Organization Theory*, Vol. 1 No. 1, pp.1-32.

Flood, R.L. (2010), “The relationship of ‘systems thinking’ to action research”, *Systemic Practice and Action Research*, Vol. 23 No. 4, pp.269-284.

Franco-Santos, M., Lucianetti, L. and Bourne, M. (2012), “Contemporary performance measurement systems: a review of their consequences and a framework for research”, *Management Accounting Research*, Vol. 23 No. 2, pp.79-119.

Franco-Santos, M., Bourne, M., Kennerley, M., Micheli, P., Martinez, V., Mason, S., Marr, B., Gray, D. and Neely, A. (2007), “Towards a definition of a business performance measurement system”, *International Journal of Operations & Production Management*, Vol. 27 No. 8, pp.784-801.

Frank, A.G., Dalenogare, L.S. and Ayala, N.F. (2019), “Industry 4.0 technologies: implementation patterns in manufacturing companies”, *International Journal of Production Economics*, Vol. 210, pp.15-26.

Gavetti, G., Greve, H.R., Levinthal, D.A. and Ocasio, W. (2012), “The behavioral theory of the firm: assessment and prospects”, *Academy of Management Annals*, Vol. 6 No. 1, pp.1-40.

Gupta, S., Meissonier, R., Drave, V.A. and Roubaud, D. (2020), "Examining the impact of Cloud ERP on sustainable performance: a dynamic capability view", *International Journal of Information Management*, Vol. 51, 102028.https://doi.org/10.1016/j.ijinfomgt.2019.10.013

Hall, M. (2008), "The effect of comprehensive performance measurement systems on role clarity, psychological empowerment and managerial performance", *Accounting, Organizations and Society*, Vol. 33 No. 2-3, pp.141-163.

Hanelt, A., Bohnsack, R., Marz, D. and Antunes Marante, C. (2021), "A systematic review of the literature on digital transformation: insights and implications for strategy and organizational change", *Journal of Management Studies*. https://doi.org/10.1111/joms.12639

Kamble, S.S., Gunasekaran, A., Ghadge, A. and Raut, R. (2020), "A performance measurement system for industry 4.0 enabled smart manufacturing system in SMMEs – a review and empirical investigation", *International Journal of Production Economics*, Vol. 229, pp. 1-15.

Kaplan, R.S. and Norton, D.P. (1993), "Putting the balanced scorecard to work", *Harvard Business Review*, Vol. 71 No. 5, pp.134-147.

Lewis, R.L., Brown, D.A. and Sutton, N.C. (2019), "Control and empowerment as an organizing paradox: implications for management control systems", *Accounting, Auditing & Accountability Journal*, Vol. 32 No. 2, pp.483-507.

Malmi, T. and Brown, D.A. (2008), "Management control systems as a package—opportunities, challenges and research directions", *Management Accounting Research*, Vol. 19 No. 4, pp.287-300.

Melnyk, S.A., Bititci, U., Platts, K., Tobias, J. and Andersen, B. (2014), "Is performance measurement and management fit for the future?", *Management Accounting Research*, Vol. 25 No. 2, pp.173-186.

Neely, A., Mills, J., Platts, K., Richards, H., Gregory, M., Bourne, M. and Kennerley, M. (2000), "Performance measurement system design: developing and testing a process-based approach", *International Journal of Operations & Production Management*, Vol. 20 No. 10, pp.1119-1145.

Nudurupati, S.S., Garengo, P. and Bititci, U.S. (2021), "Impact of the changing business environment on performance measurement and management practices", *International Journal of Production Economics*, Vol. 232

Raffoni, A., Visani, F., Bartolini, M. and Silvi, R. (2017), "Business performance analytics: exploring the potential for performance management systems", *Production Planning & Control*, Vol. 29 No. 1, pp.51-67.

Robert, M., Giuliani, P. and Gurau, C. (2020), "Implementing industry 4.0 real-time performance management systems: the case of Schneider Electric", *Production Planning & Control*, https://doi.org/10.1080/09537287.2020.1810761

Sardi, A., Garengo, P. and Bititci, U. (2019), "Measurement and management of competences by enterprise social networking", *International Journal of Productivity and Performance Management*, Vol. 68 No. 1, pp.109-126.

Sardi, A., Sorano, E., Cantino, V. and Garengo, P. (2020a), "Big data and performance measurement research: trends, evolution and future opportunities", *Measuring Business Excellence*, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/MBE-06-2019-0053

Sardi, A., Sorano, E., Ferraris, A. and Garengo, P. (2020b), "Evolutionary paths of performance measurement and management system: the longitudinal case study of a leading SME", *Measuring Business Excellence*, Vol. 24 No. 4, pp.495-510.

Smith, M. and Bititci, U. (2017), "Interplay between performance measurement and management, employee engagement and performance", *International Journal of Operations & Production Management*, Vol. 37 No. 9, pp.1207-1228.

Tessier, S. and Otley, D. (2012), "A conceptual development of Simons' Levers of Control framework", *Management Accounting Research*, Vol. 23 No. 3, pp.171-185.

Trotta, D. and Garengo, P. (2019), "Assessing Industry 4.0 maturity: an essential scale for SMEs", *8th International Conference on Industrial Technology and Management (ICITM)*, IEEE, pp.69-74.

Vallurupalli, V. and Bose, I. (2018), "Business intelligence for performance measurement: a case based analysis", *Decision Support Systems*, Vol. 111, pp.72-85.

Yin, R.K. (2014), Case study research: Design and methods, SAGE, Los Angeles, CA.

DOI: 10.18261/9788215034393-2019-06

6. Balanced Scorecard and Hoshin Kanri: Why and how they might be used together

EIRIK B. HAMRE KORSEN
Institutt for Industriell økonomi og teknologiledelse, NTNU i Gjøvik

SAMMENDRAG En viktig ledelsesutfordring er å sikre at kortsiktige mål og prioriteringer i den daglige driften bygger oppunder organisasjonenes langsiktige strategi. En rekke styringsverktøy i ulike grener av faglitteraturen har blitt foreslått for å sikre denne koblingen. I dette kapittelet undersøkes hvordan styringsverktøyet «Hoshin Kanri» kan benyttes sammen med «balansert målstyring» («The Balanced Scorecard», BSC) for å sikre at enhetenes kortsiktige mål bidrar til å realisere organisasjonens strategi. BSC er det mest velkjente og brukte styringsverktøyet. Styrken til BSC er hvordan en kan kom-munisere organisasjonenes langsiktige mål på en balansert måte ved hjelp av de fire per-spektivene: økonomi, kunder, interne prosesser og læring og vekst. Hoshin Kanri (HK), som opprinnelig kommer fra Japan, er betydelig mindre kjent. Det er et helhetlig sty-ringssystem innen kvalitetsledelse og har blitt mer populært de siste årene sammen med ledelseskonseptet «Lean». Styrken til HK er hvordan det involverer ledere og ansatte i utrulling av strategien igjennom en iterativ prosess hvor de i felleskap prioriterer kortsik-tige mål som bygger oppunder den langsiktige strategien.

Eksisterende litteratur diskuterer på teoretisk grunnlag hvordan HK og BSC kan utfylle hverandre, men det er utført svært lite empirisk forskning på samspillet mellom verktøyene. I dette kapittelet bidrar jeg med en casestudie fra en norsk vareproduserende organisasjon. Her viser jeg konkret hvilke roller BSC og HK har i et kombinert styringssystem, og hvordan de er koblet sammen. HK inkluderer teknikker som kan øke engasjementet blant ansatte og bidra til å forankre strategien. Ved hjelp av en målmatrise kalt «X-matrix» tydeliggjør HK koblingen mellom organisasjonens langsiktige strategiske mål og kortsiktige mål på lavere nivå i organisasjonen. I casen viser det seg at de som har jobbet systematisk med å implementere et kombinert styringssystem, opplever en bedre strategisk kobling til den daglige driften og økt engasjement blant ansatte. I diskusjonen identifiserer jeg noen ledelsesfaktorer som har bidratt til å øke den strategiske koblingen og identifiserer behovet for videre forskning. Til slutt tilbyr jeg en konklusjon hvor jeg anbefaler ledere å utforske og vurdere HK som et styringsverktøy da det er mer fleksibelt enn BSC.

NØKKELORD ledelsesmodeller | styringssystemer | strategi | balansert målstyring | Hoshin Kanri

ABSTRACT Aligning day-to-day operations with the company's long-term strategy is a challenging managerial task. This paper explores how Hoshin Kanri (HK), from Total Quality Management, can complement the Balanced Scorecard (BSC), from strategic management, to increase the company's strategic alignment. Previous studies have discussed this combination of management tools theoretically, but they are sparse on empirical evidence. The contribution of this paper is to demonstrate empirically how HK can complement the BSC, so that lower levels of the organization can link their short-term goals and improvement initiatives to the organization's strategy. Based on the findings, I recommend managers to learn and adopt the HK as a complement to the BSC. I specify the roles of the two tools and discuss what is required to make the combination work. In the end, I also suggest future research opportunities.

MERKNADER

Jeg vil takke deltakere på Fjordkonferansen 2018, tre anonyme fagfeller og mine veiledere Øyvind Helgesen og Jonas Ingvaldsen for konstruktive tilbakemeldinger og gode innspill underveis. Forfatteren har ingen interessekonflikter.

6.1 INTRODUCTION

A key managerial task is to align the organization's day-to-day operations with the long-term strategy. Literature on strategic management, management accounting, and quality management have suggested a plethora of management tools to aid this alignment, yet there is no consensus on a coherent approach (Neely, 2005). Among these tools, Balance Scorecard (BSC), originating from the strategic-management literature, is probably the most commonly known and widely used (Atkinson, Kaplan, Matsumura, & Young, 2012; Hoque, 2014; Kaplan & Norton, 2008). The strength of BSC is to clarify and communicate the organization's long-term strategic goals. Less known is Hoshin Kanri (HK), originally developed as a holistic framework for Total Quality Management (Asan & Tanyaş, 2007; Melander, Löfving, Andersson, Elgh, & Thulin, 2016; Witcher & Butterworth, 1999). The strength of HK is the deployment of strategic goals through cycles of planning, execution and feedback (Asan & Tanyaş, 2007; Chiarini, 2016; Witcher & Sum Chau, 2007; Yang & Yeh, 2009).

A number of studies have proposed that organizations may achieve superior strategic alignment by adopting BSC and HK simultaneously (Asan & Tanyaş, 2007; Chiarini, 2016; Witcher & Sum Chau, 2007). By using the tools in a complementary fashion, it should be possible to capitalize on the strengths of both. Yet, these ideas remain theoretically deduced, and very few studies (Asan & Tanyaş, 2007; Chiarini, 2016) have explored what such a combination would look like in practice, and whether it would be favorable to using a single tool. As summarized by Chiarini (2016, p. 372–373), "it is not clear how and if an organization that uses BSC as a system for the design and cascading of organizational objectives […] could integrate the [HK] system into the BSC architecture".

Responding to Chiarini's (2016) challenge, this paper explores how HK can complement BSC in use. Building on a case study of a Norwegian manufacturer, I show how some units manage to use the tools synergistically. Furthermore, I find that employees reported superior strategic alignment in the units using both tools, compared to the units using only BSC.

For managers, the findings imply that HK should be considered a complementary tool to the BSC, offering a flexible approach for operational units to link their short-term goals to the organization's strategy. However, to make it work, prolonged learning, substantial employee involvement, and contextual adaptations of the tools are required.

6.2 LITERATURE REVIEW

According to Kathuria, Joshi and Porth (2007, p. 504) "[strategic] alignment requires a shared understanding of organizational goals and objectives by managers at various levels and within various units of the organizational hierarchy". The question of how to achieve strategic alignment has been discussed in the literature for decades (Malmi & Brown, 2008; Otley, 2016). Different sub-disciplines of management studies approach the question from different perspectives, using different concepts (Neely, 2005). This literature review introduces the concepts "management models" and "management tools", before explaining the BSC and HK and how the tools emerged within different disciplines and in different geographical and historical contexts. It reviews previous findings on how the tools are related and can be complementary in use.

6.2.1 MANAGEMENT MODELS AND MANAGEMENT TOOLS

In organization theory, managements models can be defined as "distinct bodies of ideas that offers organizational managers precepts of how best to fulfil their technical and social tasks" (Bodrožić & Adler, 2018, p. 86–87). Models inform the overall management approach. Examples are strategy-and-structure (Chandler, 1962) and quality management (Evans, 2011). Management concepts, for example Total Quality Management (TQM) (Evans, 2011) or Lean Production (Rolfsen, 2014; Womack, Jones, & Roos, 1990), offer more specific prescriptions. A management model can include multiple management concepts. Concepts, in turn, include multiple tools and techniques. For example, Lean Production includes just-in-time inventory management (Rolfsen, 2014), while TQM includes HK (Tennant & Roberts 2001).

In the management accounting literature, the approach to manage an organization is defined as a management control system (MCS) (Chenhall, 2003; Kennedy & Widener, 2008; Langfield-Smith, 1997; Malmi & Brown, 2008; Otley, 1999, 2016; Simons, 1995). A MCS can be seen as an over-arching system that focuses on influencing employee behavior and holding employees accountable for decision-making. Malmi and Brown (2008) argue that a MCS is a "package" of different controls: cultural, planning, cybernetic, reward and compensation, and administrative controls. These controls interact and influence each other. Cultural control includes a belief system with common values (Simons, 1995) and how groups of people socialize and create common norms and standards. Planning control is the process of setting long-term goals and developing strategy (Kaplan & Norton, 2008). Cybernetic control includes financial, non-financial or hybrid measurement systems and budgets, and is similar to performance measurement systems (Kaplan & Norton, 2008) or diagnostic control systems (Simons, 1995). Reward and compensation systems focus on motivation and the performance of individuals or groups. Administrative control is the combination of governance structures, organizational structures, policies and procedures (Malmi & Brown, 2008). Within management accounting, BSC and HK are identified as systems for both planning and cybernetic control. This paper, however, follows conventions of organization theory, and refer to BSC and HK as management tools.

6.2.2 THE BALANCE SCORECARD

The BSC is discussed extensively in the strategic management literature (Neely, 2005), and is probably the most widely used management tool for strategy deployment and performance management (Atkinson et al., 2012; Hoque, 2014; Kaplan & Norton, 2008).

When introduced in 1992, the BSC was a management innovation. BSC, together with activity based costing (ABC), responded to the ongoing discussion on how organizations' performance could be measured more broadly than solely by financial measures to become more relevant to management decisions (Atkinson et al., 2012; Johnson & Kaplan, 1987). It was also in line with the contemporary focus on productivity and operations (Womack, Jones, & Roos, 1990). The BSC has been developed together with practitioners to become a holistic framework for strategic management (Andersen, Lawrie, & Savič, 2004; Kaplan & Norton, 2008). Closely associated with the BSC is the "measurement matrix", containing key performance indicators within four perspectives; financial, customer, internal processes, and learning and growth (Kaplan & Norton, 1992, 2004, 2006, 2008). An important contribution to strategic management is how the so called "strategy map" (illustrated in figure 6.1) articulates and visualizes the strategy with cause-and-effect relationships between the perspectives, and how the organization creates long-term value for its stakeholders (Atkinson et al., 2012; Bititci, Cocca, & Ates, 2016; Kaplan & Norton, 2004).

According to Kaplan and Norton (2004), the strategy map contributes with a framework and a language for executives and managers to discuss the direction of their organization in four ways. Firstly, it balances the contradiction between long-term revenue growth by investing in intangible assets and the short-term financial performance by cutting costs. Secondly, it focuses on how the organization differentiates offerings to create customer value, through product or service attributes and customer relationships. Thirdly, it links the financial and customer outputs to the performance of critical internal processes, where it identifies strategic improvements and balances the focus between operations management, customer management, innovation, and regulatory and social processes. Finally, the strategy map aligns the development of the intangible assets in the learning and growth perspective, including developing employees, managing information systems and technology infrastructure, and developing the organizational culture and knowledge (Kaplan & Norton, 2004). The strategy map is core to understanding the BSC, and the way the strategy is communicated. Next, the four perspectives of the strategy map are briefly outlined (Atkinson et al., 2012; Kaplan & Norton, 2004):

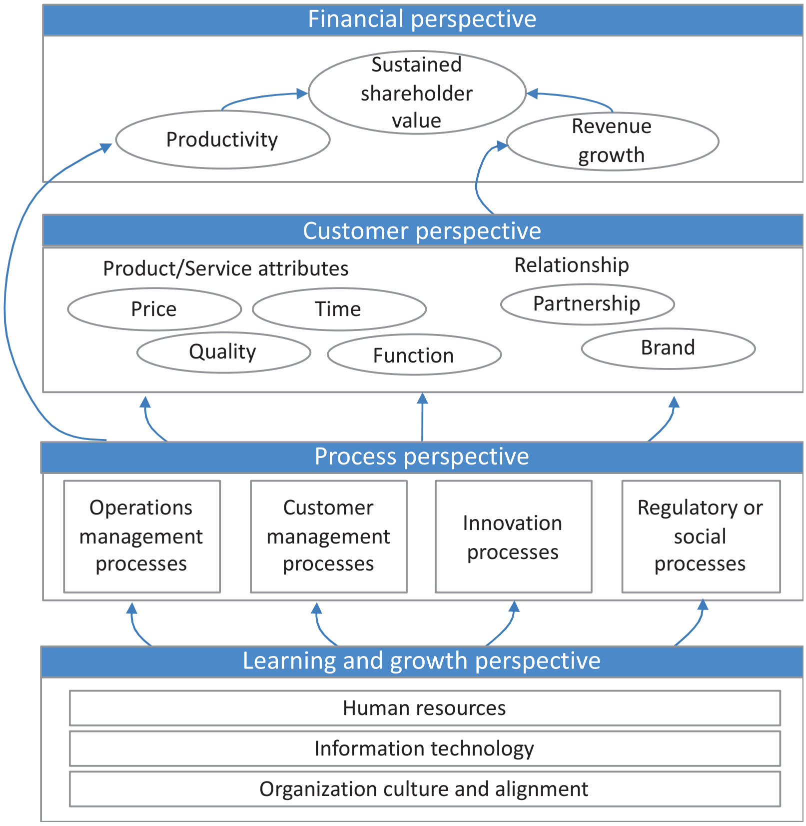

FIGURE 6.1 Illustration of Kaplan and Norton's (2004) strategy map, with the cause-and-effect relationships between the four perspectives. Source: Atkinson et al., 2012, p. 50; Kaplan & Norton, 2004.

The financial perspective expresses how the company looks to its stakeholders. It consists of lagging indicators, as a result of the underlying perspectives. It links to the internal process perspective through a productivity strategy, by cutting costs or to increasing efficiency. It links to the customer perspective through a growth strategy, by expanding the revenue streams from existing or new customer segments (Kaplan & Norton, 2004).

The customer perspective defines what creates value for target customers and sets the context for how internal processes create value. For example, if the company serve price sensitive customers, their attention should be on keeping low prices and consistent quality. Core to a strategy is to define and select customer segments and express the attributes that are important to them. These can be divided into product/service attributes: price, quality, time or functions, or relationships in the form of partnerships or brands (Kaplan & Norton, 2004).

The process perspective defines how operational processes meet the objectives of both financial and customer perspectives. It also defines what is essential for customer management, innovation, and regulatory and social processes to satisfy the customer perspective in the long term. The lead-time between the decision, the action and when the effect can be measured is a challenge for managers. Operational activities are managed from day-to-day, while the accumulated performance is measured in six to 12 months. Innovation processes can have a lead-time of two to four years before achieving measurable results (Kaplan & Norton, 2004).

The learning and growth perspective can be divided into three categories of intangible assets. Human resources focus on developing the employees' skills, talents and knowledge. Information technology includes sufficient infrastructure and data supporting the value creation. Organization development is to build a culture for adapting to a changing environment and conforming to the organization's strategy. There is a long lead-time from investments in human resources, information infrastructure and organization development to tangible effects that can be measured (Kaplan & Norton, 2004).

6.2.3 HOSHIN KANRI

HK is an overall framework for TQM, developed in Japan in the 1960s (Liker & Convis, 2012; Shimokawa & Fujimoto, 2009; Witcher & Butterworth, 1999; Womack et al., 1990). HK aided corporate managers in coordinating strategy deployment across functions and hierarchies (Witcher & Sum Chau, 2007). Central to TQM is the Plan-Do-Check-Act (PDCA) cycle for improvement (Evans, 2011; Witcher & Sum Chau, 2007). Witcher and Butterworth (1999) operationalize the strategy process as a PDCA-cycle called FAIR, based on the first letters of "Focus", "Alignment", "Integration" and "Review". Focus is the process of setting strategic priorities, representing "act". Alignment of the strategy represents "plan". Integration of the plans into daily management represents "do". Review and control through self-assessment represent "check". Taken together, the FAIR framework prescribes iterative loops of goal-setting, actions, reporting and control (Witcher & Butterworth, 1999).

HK assumes that the organization's overall vision, mission and strategy are well defined. The top management decides on a "vital-few" strategic themes for the organization to prioritize in the upcoming year. A defining element of HK is how the strategic themes are communicated and how each operational entity decides how it can contribute to the strategic goals. This is done in an iterative process known as "catchball" (Asan & Tanyaş, 2007; Witcher & Butterworth, 1999). Catchball is a metaphor from a children's game, where the players throw the ball back and forth between one another. In the catchball process, executives and managers or managers and employees engage in a two-way dialogue where they discuss, create ideas and challenge each other on how they can improve and contribute to achieving the strategy (Witcher & Butterworth, 1999). It requires the managers to have insight into operations and the subordinates to challenge their superiors. The goal of the process is to agree upon the targets, activities and strategic projects for the upcoming period (Chiarini, 2016; Liker & Convis, 2012). The results of this process for each unit is documented in a matrix, called the X-matrix (Jackson, 2006), shown in figure 6.2.

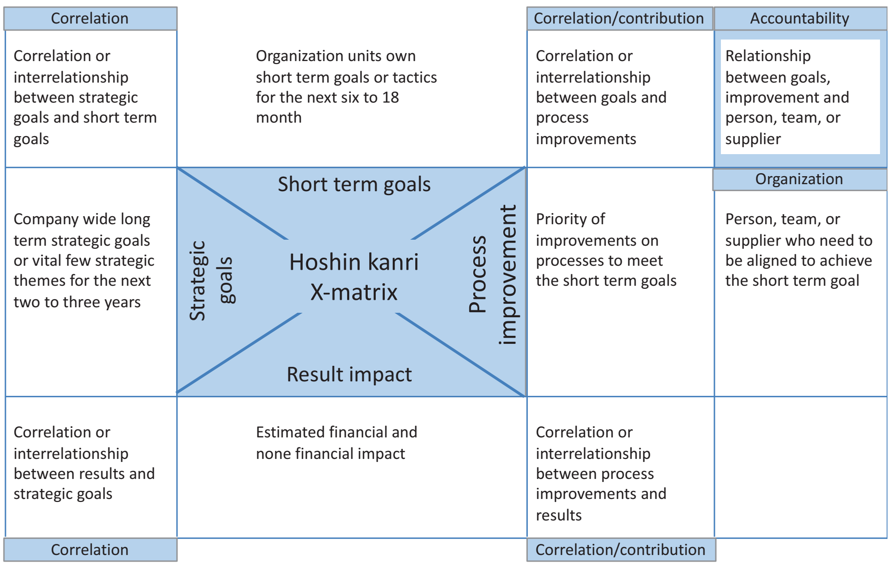

FIGURE 6.2 Illustration of the X-matrix. The matrix visualizes the relationships between strategic goals, short-term goals, process improvements and results. The figure is inspired by Jackson (2006, p. 7).

The X-matrix visualizes both local short-term goals and how these goals are linked to the organization's strategy. Strategic goals, at the left side of the matrix, are the "vital few objectives" for the current period and the next two to three years. At the top of the matrix, the department documents how it chooses to operationalize the strategy into short-term goals. The short-term goals are then explicitly linked to projects or improvement initiatives for the next six to 18 months, at the right side of the matrix. At the bottom of the matrix, the expected impact from the projects or initiatives is documented. This can be done in terms of both financial and non-financial performance indicators. In each corner of the matrix, the interrelationships or correlations between the strategy and the entity's own short-term goals, improvement projects and result indicators are illustrated, connecting the operational activity to the strategy. At the far-right side of the matrix, it is stated explicitly who is responsible for process improvements and/or achieving the short-term goals.

6.2.4 RELATED AND COMPLEMENTARY TOOLS

Although the BSC and HK emerged from two different disciplines, they both address the managerial challenge of aligning a departments' activities with the organization's strategy (Asan & Tanyaş, 2007; Chiarini, 2016; Kaplan & Norton, 2008; Nørreklit, 2000; Witcher & Sum Chau, 2007; Yang & Yeh, 2009). The tools also originated in different geographical and historical contexts. The BSC is a western or American approach which focuses on driving change (Witcher & Butterworth, 1999). It is presented as an easy-to-implement solution to improve business results, which is probably the reason for its widespread diffusion and popularity (Kaplan & Norton, 2008). HK is a Japanese approach, focusing on developing organizational capabilities, and puts more emphasis on long-term value creation (Witcher & Butterworth, 1999). It only recently received attention in the West, as a component of the widely popular management concept, lean (Netland & Powell, 2016; Witcher & Sum Chau, 2007). Compared to HK, BSC can be described as performance and target oriented, with a top-down conceptual framework. HK is more process and means oriented, striving for consensus across departments and managerial layers (Asan & Tanyaş, 2007).

In the literature, there are some relevant contributions on how BSC and HK can complement each other (Asan & Tanyaş, 2007; Chiarini, 2016; Witcher & Sum Chau, 2007; Yang & Yeh, 2009). They all suggest a combined model where the BSC visualizes and communicates the strategy, with the link to the organization's vision and mission. HK's role is to facilitate strategy deployment and implementation. Witcher and Sum Chau (2007) and Asan and Tanyaş (2007) emphasize the strength of HK for facilitating an iterative process for goal setting, reporting and control. Yang and Yeh (2009) suggest a combination where the BSC is used to define the long-term development and strategic goals, while HK is used to deploy the strategy and aid performance management in daily operations. Chiarini (2016) compared using BSC and HK for implementing a corporate social responsibility strategy. He found HK to be the more flexible compared to the BSC. The X-matrix (Jackson, 2006) in HK is more flexible since it has no predefined dimensions, compared to the strategy map in the BSC where the strategic goals need to fit within the four predefined perspectives. However, Chiarini's (2016) findings are limited to specific cases and he concludes that "it is not clear how and if an organization that uses BSC as a system for the design and cascading of organizational objectives … could integrate the [HK] system into the BSC architecture" (p. 372–373). This paper responds to Chiarini's (2016) challenge. Considering the limited empirical research and lack of practical guidelines for combining the tools, I ask:

How can Hoshin Kanri complement balanced scorecard in use?

6.3 RESEARCH DESIGN AND CONTEXT: THE CASE OF NM

The empirical findings in this paper are based on a qualitative case study of a single company using both the BSC and HK. A qualitative approach is appropriate for gaining in-depth insights in novel, previously unexplored phenomena (Eisenhardt, 1989). A single case study is suitable when asking "how", and where the phenomenon of interest is difficult to distinguish from its context (Yin, 2009).

The case company, anonymized as "Norwegian manufacturer" (NM), was purposely sampled, as the organization is using multiple management tools, including the BSC and HK. NM in its current form is a relatively young company, but its traditions go back more than a century. It is a high-technology company, designing and manufacturing both high-volume and low-volume products based on customer requirements. During the last 20 years, the company has expanded worldwide. The case study is limited to the Norwegian branch of the company.

NM is structured as a matrix organization. Product divisions with customer contact are the dominant business units. Support functions and factories are hosted by one product division but serve multiple divisions. This means that a single manager can have two roles, both as head of a division and head of a factory that serves several divisions. The Norwegian location reflects this complexity with a number of functions and factories serving several divisions.

I gathered data through an ethnographic approach (Cresswell, 2012). The interviews and observations, supported by informal conversations, were performed in parallel with the literature review. To anchor the research and identify relevant informants, I had two formal meetings with NM managers. In addition, I visited two manufacturing sites and had informal conversations with NM employees. To prepare for the interviews, I read all relevant information published on NM's website and archival data from local newspapers. Eleven semi-structured interviews were conducted from June 2017 to April 2018. The informants were middle managers of the Norwegian branch, including the CFO, the COO, two product-division managers, one quality manager, one logistics manager, the head of contract management and the quality-assurance manager. The interviews were based on an interview guide with open-ended questions, formed as a check list, to cover key topics such as organization structure, reporting structure and the use of BSC and HK and other management tools. Two of the interviews where recorded and transcribed, whereas detailed notes were taken during the other interviews.

I observed one full-day management meeting in the one business unit, participated in two management workshops, participated in one research workshop hosted by the organization, and observed a four-day quality audit by an external auditor. To observe how the management tools were used on the factory floor, I visited production sites four times. Detailed field notes were taken during and right after the visits. I also spent 17 days at the head office, which allowed me to observe and have informal conversations in between the formal meetings. I have also gathered and analyzed copies of their internal scorecards, HK-matrices and management reports.

For data analysis, I categorized the empirical material into three main clusters. The first cluster consists of interviews and observations from NM units, which actively use only the BSC. The second cluster is material from units, which use both the BSC and HK. Units in the third cluster did not actively use the BSC nor HK, and were therefore excluded from further analysis. The first and second clusters were then systematically compared as cases within the case (Eisenhardt, 1989). The two clusters where analyzed with respect to how the tools were used, processes of strategy deployment, and employees' perceived level of strategic alignment, along with emergent themes (such as the relationship to Lean management). Hence, I could systemically investigate how the tools were combined (cluster 2) and whether this combination was perceived to be superior to using solely the BSC (cluster 1 vs. cluster 2). To validate my interpretation of the data, the results were presented and discussed with the key informants who validated the findings.

6.4 RESEARCH RESULTS

Table 6.1 shows how I clustered the data in two categories: 1) units, which use only the BSC actively, and 2) units, which use both the BSC and HK actively in combination, along with the key findings.

TABLE 6.1 Overview of the two relevant data clusters and key findings

Management tools	Data sources (number of times in brackets)	Key findings
BSC (Cluster 1)	◗ Interview with CFO (2) and finance function ◗ Interview with head of production division 2 (1) ◗ Interview with head of logistics, support function (1) ◗ Strategy map document ◗ Management reports ◗ Observations of quality audit	◗ Yearly business review and strategy process, bottom-up and top-down ◗ Monthly reporting to top-management, high-level summary ◗ Scorecard as a "once a year exercise" ◗ Difficult to link strategy to day-to-day actions ◗ Limited knowledge and ownership among employees
BSC and HK (Cluster 2)	◗ Interview with COO (2), and head of all factories ◗ Interview with head of product division 1, and head of one factory (1) ◗ HK X-matrix document ◗ Observations in workshop with factory management ◗ Visits to production sites (4) ◗ Observations of quality audit	◗ HK fits with lean/continuous improvement focus ◗ No quick-fix. Three years of experience, and still developing ◗ BSC top-down vs HK iterative and bottom-up ◗ Have invested in knowledge and learning the catchball process ◗ Engaged employees ◗ Superior strategic alignment

The next sections elaborate on the key findings in table 6.1. First, I describe how NM uses the BSC and the strategy map. Second, I describe how some units successfully use HK to complement the BSC. Finally, I compare perceived outcomes in the units that use only the BSC with the units that combine BSC with HK.

6.4.1 THE USE OF THE BSC AND THE STRATEGY MAP

NM uses the BSC for two purposes: Firstly, to communicate the strategy for the next three years in a strategy map, and secondly, as a framework for monthly reporting to the top-management team.

The strategy map is updated once a year through a strategic review initiated by the CFO. The CFO conducts business reviews with each division's management, where the existing strategy and the business outlook for the next one to three years are discussed. The outputs from the business reviews are accumulated and consolidated into an overall strategy, described in the strategy map.

The strategy map at NM has similarities with the strategy map described by Kaplan and Norton (2004), illustrated in figure 6.1. It states the overall strategic goals and financial performance targets for each of the four perspectives financial, customer, internal business processes, and learning and growth. For example, in the learning and growth perspective, the financial performance target is “10 % R&D of sales”. For each of the four perspectives, four critical success factors are defined as non-financial achievements necessary to meet the strategic goals. For example, a critical success factor for the internal business process perspective is “Lean and effective business organization enabling NM to reach strategic goals”. The content of the strategy map should be valid for all business units. The cause-and-effects relationship between the four perspectives in NM’s strategy map is implicit in the relationship between the critical success factors and the strategic goals. The strategy map is communicated to the managers of the divisions and the business units, including factories and functions, as a top-down process through a strategy seminar.

The BSC format with the four perspectives is used for monthly reporting. It is a combination of recorded financial data from the ERP-system (including accounting data) and written monthly reports from the divisions. The input is coordinated and edited by the CFO and a controller before it is presented and discussed in a management meeting. My analysis of the reports show that the financial figures are most thoroughly explained. The other three perspectives are summarized more briefly.

> “I get standard reports based on Balance Scorecard from all entities and edit this to a management summary. Much of the details are then left out.” (CFO)

Although the BSC format is mandatory when reporting to the management group, the managers choose which tools to apply within their own areas of responsibility. A few units use the BSC on a business unit level. Despite their intentions of using the BSC to focus the units toward the strategy, they find it challenging for several reasons. Two out of three find it difficult either to define or measure key performance indicators (KPI) for operations, as the functions’ day-to-day activities do not fit into the BSC format or it is difficult to gather relevant performance data. Their knowledge about NM’s strategy and experience in using the BSC varies, and the company has offered little training in this respect. Therefore, the departmental scorecard is not seen as a “living document”, but rather as “an exercise, done once a year”. Another common challenge is that other forms of reporting, concerning budgets, health-environment-safety (HES) and quality have a longer tradition within NM with IT-system support, and are important to comply with the external audits.

6.4.2 THE USE OF HOSHIN KANRI IN COMBINATION WITH BSC

The COO together with his team of factory managers started using HK to reinforce the principles of Lean production on the factory floor. The management team under the COO chose HK because of its origin in the Toyota production system and Lean thinking (Liker & Convis, 2012; Netland & Powell, 2016). HK was implemented on their own initiative and had at the time of data collection been used for three years. As part of the process of identifying how they could use HK, managers collaborated with an external consultant, who explained the underlying theory and HK's relationship to other lean management principles and techniques.

HK receives most attention when the factory units start to develop the X-matrices right after top management decides on the strategy map, normally at the end of August or early September. The process combines top-down and bottom-up influences. The strategy map is perceived as a top-down communication of NM's strategic goals. Their own HK-process is bottom-up and iterative.

To kick off the development of next year's X-matrix, managers and employees meet for a one-day workshop on an off-site location. Even though they have used the HK for three years, they start the workshop with an external consultant to refresh their understanding of HK and Lean production. During the workshop, they achieve two important goals. Firstly, all participants achieve a common interpretation of the strategy map, last year's achievements and the gaps in their own performance. Secondly, they begin the catchball process to define short-term goals for the next year, prioritize improvement initiatives and define relevant measures. The short-term goals, improvements initiatives and measures are documented according to the X-matrix format (see figure 6.2).

The catchball process continues after the workshop. The managers align their ambitions and short-term goals with available resources and the budget. In the process, they also review the HES and quality requirement to achieve compliance. All the factory-level goals and priorities are in the end accumulated into an overall X-matrix for the management team.

> "The Hoshin Kanri [matrix] is not mine. It is the managers who develop this together and are depending on each other to deliver the agreed results." (COO)

On the shop floor, different teams use different whiteboards with productivity measures, HES-measures, data on sick leave and improvement activities. The X-matrix is posed next to the productivity measures. In the factories, they have daily morning meetings for the teams, and weekly meetings between managers and teams. In those meetings, ongoing activities, relevant measures and improvements, as arranged in the X-matrix, are discussed.

> "In the morning meetings, the team goes through the board. My impression is that the measures get the attention since it's easy to report and explain deviations." (Product division manager 1)

The manager of product division 1 reported increased employee engagement. Use of the X-matrix focuses on activities to increase productivity, while also paying attention to employee participation and reduction of sick leave.

> "I can see the performance measures are improving, but the best part is that now employees come up to me with enthusiasm to tell me success stories about how they figured out how to improve their work." (Product division manager 1)

6.4.3 BSC VERSUS HOSHIN KANRI IN COMBINATION WITH BSC

When comparing the observations and interviews from the units who use only the BSC (cluster 1) to the units who use HK in combination with BSC (cluster 2) there are interesting differences. Units in cluster 2 experience superior strategic alignment with a closer link between the strategic goals and the day-to-day actions.

> "With Hoshin, employees express by themselves how they will contribute, and then they are measured on what they have said. Then some changes just happened, and we have gained momentum in our lean implementation. I believe Hoshin is one of the reasons for the success." (COO)

Units in cluster 2 also report that HK is used on the shop floor and in the morning meetings on a daily basis, compared to cluster 1 where BSC is a "once a year exercise". One of the reasons for the differences might be that the units in cluster 2 have invested time in increasing their knowledge about HK and the catchball process. In contrast, employees in cluster 1 do not report on any training in using the BSC.

> "Before each unit makes their own Hoshin, there is a one-day kick-off. There everyone is together, and we have some training before a half-day workshop. After that each unit gets a deadline to complete its X-matrix." (COO)

6.5 DISCUSSION

This paper contributes with empirical evidence on the BSC-HK relationship, whereas other studies have theoretically discussed how they could or should be combined (Asan & Tanyaş, 2007; Chiarini, 2016; Witcher & Sum Chau, 2007; Yang & Yeh, 2009). The case study demonstrates that HK indeed can complement the BSC in use, and shows how some units managed to use the tools synergistically. These units balanced the top-down approach of the BSC with the bottom-up approach of the HK in the process of strategy formulation and deployment. The role of the BSC with the strategy map, is to articulate and visualize the strategy and the cause-and-effect between the four perspectives; financial, customer, internal processes and learning and growth. This creates a more collective interpretation and understanding of the strategic goals. The role of HK is to facilitate the process between the organizational levels in the catchball process and document the agreed goals, process improvements and results indicators in an X-matrix. The X-matrix also illustrates the link between local goals and the strategy, and addresses who is responsible for each goal. The BSC and HK were explicitly linked by treating the BSC's "strategic goals" as HK's "vital few" strategic themes.

In the case of NM, units who use HK in combination with BSC report superior strategic alignment, increased employee engagement and improved performance, compared to those units using only the BSC. However, I will not claim that HK is the reason for these results. Four managerial factors seem to have influenced the successful adoption of HK.

Firstly, the management team was involved in choosing HK as a management tool that fitted their context, including the lean implementation. This ensures a strong connection between the management tool and the management concept they prefer.

Secondly, the units invested significant efforts in building knowledge on how to adopt HK. It offered a workable solution to linking strategic goals to short-term goals. This helped managers and employees to achieve a comprehensive understanding and a common language.

Thirdly, through the catchball process, they involved managers and employees on all levels in the strategy-deployment process. This created a coherent apprehension of the strategy, a link between the long-term and short-term goals, and increased the probability of employee commitment as they were involved in setting their own goals (Hope, Bunce & Röösli, 2011).

Finally, the flexibility of HK made it possible to differentiate the strategic focus and the short-term goals between the units. HK's flexibility also meant it could incorporate additional requirements such as budget, HES, and quality, leading to a more coherent management approach at the unit level.

The first three aspects are likely to be generalizable to any management tool; any would even apply when the BSC is used in isolation. It is a managerial task to identify which management tool fits the context, build the organization's capability to use the tool, and engage employees. I cannot see any reason why a process similar to the catchball process would not work within the framework of BSC. Concerning the forth aspect, the interpretation of the BSC as a rigid target oriented top-down reporting system limited to the four perspectives is the main challenge (Asan & Tanyaş, 2007; Chiarini, 2016). Although these perspectives are highly relevant at the top-management level, at lower levels of the organization, there is a need for greater flexibility in how to set goals and follow up on measures.

This study demonstrates that the HK can complement BSC in offering a more flexible approach for lower levels units. However, this case study has some limitations and additional research is necessary. First, the evidence is based on a single case where only a few units use a combined model with the BSC and the HK. Additional cases are needed to validate the results from this study and see whether these can be generalized, either across organizations or between different departments within an organization. Secondly, this study is also limited to the specific management tools, the BSC and the HK. There are other management tools for strategic management from different traditions, for example the "Tableau de bord" developed in France in the 1930s (Bourguignon, A., Malleret, V. & Nørreklit, H., 2003; Lebas, M, 1994). Future research can compare different management tools from different traditions to identify their strength and to what extent they can be combined. In addition, future research can better understand the contribution from the management tool in respect to achieving superior strategic alignment. It is possible to identify managerial factors that exist across different management tools, or are independent of the management tool, which need to be in place for managers to successfully link the day-to-day operations to the long-term strategy.

6.6 CONCLUSION

This case study demonstrates that HK has the flexibility to meet the different contextual needs at lower levels of the organization (Chiarini, 2016). The BSC strength is to articulate and communicate the strategy. HK can complement the BSC to link an organization's day-to-day operations with the long-term strategy. I would highly recommend managers who experience difficulties in achieving strategic alignment, to learn and adopt the techniques of HK, even if they are currently using the BSC. In particular, they should consider adopting the catchball process to engage employees and the X-matrix to link the short-term goals to the strategy. It is no quick fix though. Both managers and employees need training and experience to build their capabilities on how to use the tool within their organizational context.

REFERENCES

Andersen, H. V., Lawrie, G., & Savič, N. (2004). Effective quality management through third-generation BSC. *International Journal of Productivity and Performance Management*, *53*(7), 634–645. https://doi.org/10.1108/17410400410561259

Asan, Ş. S., & Tanyaş, M. (2007). Integrating Hoshin Kanri and the BSC for strategic management: The case of higher education. *Total Quality Management and Business Excellence*, *18*(9), 999–1014. https://doi.org/10.1080/14783360701592604

Atkinson, A. A., Kaplan, R. S., Matsumura, E. M., & Young, S. M. (2012). *Managment accounting information for decision making and strategy executiong* (Sixth edit). Pearson Education Limited.

Bititci, U., Cocca, P., & Ates, A. (2016). Impact of visual performance management systems on the performance management practices of organisations. *International Journal of Production Research*, *546*(6), 1571–1593. https://doi.org/10.1080/00207543.2015.1005770

Bodrožić, Z., & Adler, P. S. (2018). *The Evolution of Management Models: A Neo-Schumpeterian Theory. Administrative Science Quarterly* (Vol. 63). https://doi.org/10.1177/0001839217704811

Bogsnes, B. (2009). *Implementing Beyond Budgeting: unlocking the performance potential*. New Jersey: John Wiley & Sons, Inc.

Bourguignon, V., Malleret, V, & Nørreklit, H. (2004) The American balanced scorecard versus the French tableau de bord: The ideological dimension. *Management Accounting Research*, 15 (2), 107-134. https://doi.org/10.1016/j.mar.2003.12.006

Chandler, A. D. (1962) *Strategy and Structure: Chapters in the History of the Industrial Enterprise*. Cambridge, MA: MIT Press.

Chenhall, R. H. (2003). Management control systems design within its organizational context: findings from contingency-based research and directions for the future, *28*, 127–168. https://doi.org/10.1016/S0361-3682(01)00027-7

Chiarini, A. (2016). Corporate social responsibility strategies using the TQM. *The TQM Journal*, *28*(3), 360–376. https://doi.org/10.1108/TQM-03-2014-0035

Cresswell, J. W. (2012) *Quality Inquiry and Research Design. Choosing Among Five Appraches*. Third edition, Sage Publications.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review*, *14 SRC*-(4), 532–550.

Evans, J. R. (2011). *Quality Management, organization and strategy* (6th ed.). South-Western Cengage Learning.

Hope, J., Bunce, P., & Röösli, F. (2011). *The Leader's Dilemma - how to build an empowered and adaptive organization without losing control*. West Sussex: John Wiley & Sons, Ltd.

Hoque, Z. (2014). 20 years of studies on the BSC: Trends, accomplishments, gaps and opportunities for future research. *British Accounting Review*, *46*(1), 33–59. https://doi.org/10.1016/j.bar.2013.10.003

Jackson, T. (2006). *Hoshin Kanri for the lean enterprise*. New York: Productivity Press.

Johnson, H. T., & Kaplan, R. S. (1987). *Relevance Lost: The Rise and Fall of Management Accounting*. Boston: Harvard Business School Press.

Kaplan, R. S., & Norton, D. P. (1992). The BSCs, Measures that drive performance. *Harvard Business Review*, *70*(1), 71 (9).

Kaplan, R. S., & Norton, D. P. (2004). *Strategy Maps Converting Intangible Assets into Tangible Outcomes*. Boston: Harvard Business School Publishing Corporation.

Kaplan, R. S., & Norton, D. P. (2006). *Alignment: Using the BSC to Create Corporate Synergies*. Boston: Harvard Business School Press.

Kaplan, R. S., & Norton, D. P. (2008). *The Execution Premium: Linking Strategy to Operation for Competitive Advantage*. Boston: Harvard Business School Press.

Kathuria, R., Joshi, M. P., & Porth, S. J. (2007). Organizational alignment and performance: past, present and future. *Management Decision*, *45*(3), 503–517. https://doi.org/10.1108/00251740710745106

Kennedy, F. A., & Widener, S. K. (2008). A control framework: Insights from evidence on lean accounting. *Management Accounting Research*, *19*(4), 301–323. https://doi.org/10.1016/j.mar.2008.01.001

Langfield-Smith, K. (1997). Management control systems and strategy: A critical review. *Accounting, Organizations and Society*, 22(2), 207–232. https://doi.org/10.1016/S0361-3682(95)00040-2

Lebas, M. (1994). Managerial Accounting in France: Overview of Past Tradition and Current Practice 1 Managerial Accounting in France: Overview of Past Tradition and Current Practice, 3 (December 1992), 1–20.

Liker, J. K., & Convis, G. L. (2012). *The Toyota Way to Lean Leadership, Achiving and Sustaining Excellence Through Leadership Development*. New York: McGraw Hill.

Malmi, T., & Brown, D. A. (2008). Management control systems as a package-Opportunities, challenges and research directions. *Management Accounting Research*, *19*(4), 287–300. https://doi.org/10.1016/j.mar.2008.09.003

Melander, A., Löfving, M., Andersson, D., Elgh, F., & Thulin, M. (2016). Introducing the Hoshin Kanri strategic management system in manufacturing SMEs. *Management Decision*, *54*(10), 2507–2523. https://doi.org/10.1108/MD-03-2016-0148

Neely, A. (2005). The evolution of performance measurement research. *International Journal of Operations & Production Management, 25*(12), 1264–1277. https://doi.org/10.1108/01443570510633648

Netland, T. H., & Powell, D. J. (2016). *The Routledge companion to lean management*. New York: Routledge, Taylor and Francis Group.

Nørreklit, H. (2000). The balance on the BSC – A critical analysis of some of its assumptions. *Management Accounting Research*, *11*(1), 65–88. https://doi.org/10.1006/mare.1999.0121

Otley, D. (1999). Performance management : a framework for management control systems research. *Management Accounting Research*, *10*(September), 363–382.

Otley, D. (2016). The contingency theory of management accounting and control: 1980–2014. *Management Accounting Research*, *31*, 45–62. https://doi.org/10.1016/j.mar.2016.02.001

Rolfsen, M. (2014). *Lean blir norsk, lean i den norske samarbeidsmodellen*. Bergen: Fagbokforlaget.

Shimokawa, K., & Fujimoto, T. (2009). *The Birth of Lean*. Cambridge, Massachussetts: The Lean Enterprise Institute.

Simons, R. (1995). *Levers of control: how managers use innovative control systems to drive strategic renewal*. Boston: Harvard Business School Press.

Tennant, C., & Roberts, P. (2001). Hoshin Kanri: A Tool for Strategic Policy Deployment. *Knowledge and Process Management*, 8(4), 262–269. https://doi.org/10.1002/kpm.121

Witcher, B. J., & Butterworth, R. (1999). Hoshin Kanri: How Xerox manages. *Long Range Planning*, *32*(3), 323–332. https://doi.org/10.1016/S0024-6301(99)00036-9

Witcher, B. J., & Sum Chau, V. (2007). BSC and hoshin kanri : dynamic capabilities for managing strategic fit. *Management Decision*, *45*(3), 518–538. https://doi.org/10.1108/00251740710745115

Womack, J. P., Jones, D. T., & Roos, D. (1990). The Machine that Changed the World: The Story of Lean Production. *World*. https://doi.org/10.1016/0024-6301(92)90400-V

Yang, C. C., & Yeh, T. M. (2009). An integrated implementation model of strategic planning, BSC and Hoshin management. *Total Quality Management and Business Excellence*, *20*(9), 989–1002. https://doi.org/10.1080/14783360903181800

Yin, R. K. (2009). *Case Study Research: Design and Methods* (4th Ed.). Thousand Oaks, CA: Sage.

Digitalization Studied From a Performance Measurement and Management Perspective: Augmented Intelligence?

Eirik B. Hamre Korsen
Assistant Professor/PhD candidate, Norwegian University of Science and Technology

Jonas A. Ingvaldsen
Professor, Norwegian University of Science and Technology

Abstract
Industry 4.0 is predicted to radically change manufacturing organizations. Cognitive technologies, in the form of business intelligence, big data, and artificial intelligence, go beyond the automation of manual tasks to replace or support decision making, planning, and problem solving. To understand how cognitive technologies are deployed. and their consequences for how work is performed and managed, this paper analyses and compares three cases from Norwegian manufacturing. Through the theoretical lens of performance measurement and management, the article identifies that the deployment of cognitive technologies appears to be incremental and bound to particular functions. The technologies do not replace work; rather they are implemented to support employees in problem solving and decision making. Hence, existing organizational norms of empowerment and broad involvement of employees in continuous improvement are reinforced. A key factor for success is how existing employees' competencies are built to make them "bilingual", so that they understand both the material processes and how these are represented in a digital language.

Keywords: Digitalization, Digital transformation, Cognitive technologies, Industry 4.0, Performance measurement, Performance management, Empowerment.

Nøkkelord: Digitalisering, Digital transformasjon, Kognitiv teknologi, Industri 4.0, Myndiggjøring, Prestasjonsmåling, Prestasjonsledelse, Virksomhetsstyring

This paper is awaiting publication and is not included in NTNU Open

ISBN 978-82-326-5588-5 (printed ver.)
ISBN 978-82-326-6557-0 (electronic ver.)
ISSN 1503-8181 (printed ver.)
ISSN 2703-8084 (online ver.)

NTNU

Norwegian University of
Science and Technology