Sustainable circular economy: Unpacking the unintended consequences of digital transformation in Japanese SMEs☆

Leanne Chung [a], Kim Hua Tan [b,*], Osamu Yoshie [c]

[a] *Cardiff Business School, United Kingdom*
[b] *Nottingham University Business School, England, United Kingdom*
[c] *Waseda University, Japan*

ARTICLE INFO

ABSTRACT

Digital transformation (DX) and the shift toward a sustainable circular economy are reshaping industries, raising both practical and theoretical questions about power, collaboration, and ecosystem dynamics. While DX offers opportunities for efficiency and sustainability, it also induces unintended consequences—particularly in altering inter-organizational power relations and blurring traditional industrial boundaries. Drawing on circular economy and ecosystem perspectives, this study investigates these unintended consequences through multiple in-depth case studies of Japanese SMEs. The research reveals how organisations renegotiate constraints and resources to adapt to evolving digital ecosystems. Unlike much of the existing literature that focuses on benefits, this paper uniquely explores the dual nature of unintended consequences—highlighting not only risks but rather, some present exploitable opportunities. The findings offer novel theoretical insights into digital circular economy-era and provide actionable guidance for policymakers and practitioners navigating digital transformation.

1. Introduction

The circular economy aspires to eliminate waste and promote resource reuse, regeneration, and efficiency. DX necessitates digital technologies integration into all aspects of operations, leading to significant improvement in service delivery, operational efficiency, and citizen engagement. Hence, the synergy between DX and circular economy doubles their combined potential to create resilient systems that could balance economic growth, sustainable resource reuse, and social fairness (Behl et al., 2023). This convergence provides great opportunities for public sectors and enterprises to redefine operations and governance models, as well as improve efficiency and environmental impacts.

In light of this, interest in supply chain digitalisation have grown significantly in recent years (Kittipanya-Ngam and Tan, 2020; He et al., 2020; Tan, 2023). Many public sectors and firms (multinationals and SMEs alike) have stepped up their digital transformations (DX) aiming to revamp and reinvigorate their operations to better engage, and create new values for their customers, suppliers and communities. Nonetheless, the fast pace of technologies evolution and rapid roll out of digitalisation created unforeseen effects that left many firms stumbled along the digital transformation journey.

Current studies have been largely focused on the positive side of DX which can provide immediate impact on productivity (Kittipanya-Ngam and Tan, 2020; Davenport and Westerman, 2018). However, the long-term and indirect effects of digital transformation have been largely ignored. A potential dark side of digital transformation is a drastic shift in supply chain ecosystems and power relationships between enterprises. Often, manufacturing SMEs need to relax various constraints and acquire critical resources in the digitalisation processes to facilitate collaboration and trust across organizational boundaries. This, in turn, will lead to a structural change in the power relationship between SMEs and large corporations, as well as its supply chain ecosystem of customers, suppliers, and subcontractors. However, the debate on the 'dark side' of digital transformation is still limited.

Using the organizational theory lens, Selznick (1948) argued that unintended consequences are the result of environmental uncertainty and the bounded rationality of organizational actors. Therefore, predicting the long-term impact of digitalisation in an uncertain and complex world is not easy. Tan et al. (2017); Tan and Rae (2009) argue that the impact can be dependent on firm size, industry, and the environmental and social contexts the firm located in. Hence, the short term and

long-term unintended implications of digitalisation on a firm can be very different. For instance, digital servitisation transforms value creation processes and subsequently benefits all firms in supply chains. However, upstream firms are particularly vulnerable to becoming disadvantaged echelons in a digitally servitised supply chain, as they are positioned far away from customers (Mosch et al., 2021). Given that digital transformation is an ongoing process, not a short-term project with a defined goal, the unintended consequence of digitalisation on supply chain relationships in the longer term is worth deeper attention.

From a sustainable circular economy and ecosystem perspective, the unintended consequences of digitalisation on supply chain relationships are likely to unfold more clearly over the longer term, as interdependencies among supply chain actors deepen and evolve. These consequences—ranging from shifts in power dynamics to the marginalisation of smaller players—may not be immediately apparent but can significantly reshape value creation and power within supply chain ecosystems.

Using an in-depth case study and a circular economy perspective, this study will unveil latent effects and unpack the potential co-evolution of firms and technologies—offering critical insights into how digital transformations may cause unintended consequences that could reconfigure collaborative practices, redistribute responsibilities, and reshape sustainability outcomes.

Hence, this paper aims to unpack the unintended impacts of digital transformation on firms' operations, as well as their related consequences to supply chain relationships. In term of research scope, this paper would like to examine the challenges and unintended consequences faced by Japanese SMEs in the digital transformation journey. This paper intends to explore how could SMEs overemphasize the positive benefits of DX and underestimate the unintended consequences of digitalisation, and, perhaps most of all, the scale of the unforeseen consequences weighing down on them.

SMEs have been pivotal in driving the swift industrialization of numerous Far East countries, contributing significantly to the development and commercialization of new products, processes, and technologies (Li and Tan, 2019). Gaining a deeper insight into the challenges SMEs encounter during their digital transformation journey, along with understanding the unforeseen consequences of digitalisation, will broaden our knowledge in operations management theories. This knowledge, in turn, empowers SME practitioners to effectively influence business growth via digitalisation. Several compelling reasons justify the focus on Japanese SMEs in this study. Firstly, Japan stands as one of Asia's foremost technology nations, making any comprehensive operations or strategic theory incomplete without its inclusion. Secondly, given the shared cultural elements with Korea, China, and Taiwan, the Japanese experience can offer insights into the future digital transformation journeys of firms in Asia. Lastly, as Japan remains a dominant economic power, gaining a deeper understanding of Japanese firms holds significant practical implications for Western companies engaged in business dealings within Japan.

This paper can contribute to both theory building and provide important practical implications by: (a) enriching the conceptual understanding of the unintended consequences of digital transformation; (b) providing managers important insights and practical advice for riding on the digitalisation to enhance operations and supply chain performance; and (c) delivering actionable insights for public sectors in developing citizen-centric governance models that maximize social capital and minimize environmental impact. The remainder of the paper is structured as follows. The next section reviews the literature on the digital transformation and unintended consequences. Section three outlines the research methodology. The findings are presented in section four, followed by a discussion of their significance and contribution. Finally, limitations and suggestions for future works are presented.

2. Theoretical background

Many authors (Kittipanya-Ngam and Tan, 2020; He et al., 2020; Bughin et al., 2018) refer digital transformation as a process of rebuilding management and business processes by adopting a variety of digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), 3D printing, big data analytics and digital platforms, which leads to improved productivity, new business models and the provision of better value-added services to customers. Hence, digital transformation entails digitisation and digitalisation.

Fig. 1 indicates that digitisation is foundational and an enabler for digitalisation. The digitisation process necessitates the conversion of non-digital (analog) into a digital format. For example, a surface levelling measurement is converted from the traditional 'bubble' reading to an electronic one (Li and Tan, 2019). While digitisation is the connection between the analog world and software, digitalisation leverage the digitised data and digital technologies to improve productivities, change and automate processes. For example, automatic bank transfer payments based on the invoice due date. DX is the process of moving to a digital business operation via the adoption of digital technologies to change business models to enhance customer added values and create new revenue opportunities. John Deere, for example, using the Internet of Things (IoT) ecosystem to enhance the digital services and value delivered to customers by its machinery to differentiates itself from competitors (Deere, 2023). Interestingly, the triangle of DX could be further categorised into two stages. It is not possible to realise DX to develop *proactive* customer focused business models suddenly. Firms should incrementally digitised data and digitalised business processes as first journey in the digital transformation. Hence, digitisation and digitalisation can be seen as *reactive* and foundational to DX (Yasuoka, 2023).

2.1. The "Darkside" of digital transformation

In literature, some authors use 'darkside' to refer to the unintended consequences of digital transformation (Trittin-Ulbrich et al., 2021; Verbeke and Hutzschenreuter, 2021). It is crucial to differentiate between unintended and undesired consequences. Unintended consequences are those not anticipated and addressed beforehand, while undesired consequences are deemed harmful, yet accepted or tolerated, with the associated risk. Consequences can be both intended and desired, as well as unintended or undesirable (Healy, 2012). Unintended consequences refer to outcomes that were not anticipated or planned for. They can be positive, negative, or neutral. For example, creating a public park might unintentionally lead to an increase in nearby property values—a positive effect—or to more traffic congestion in the area, which might not have been expected. Undesirable outcomes, on the other hand, are specifically negative results—outcomes that people generally do not want, regardless of whether they were intended. So, if a medication causes severe side effects, that's undesirable, even if it was expected and accepted as part of the risk. In short, unintended can be equivalent to be unplanned, while undesirable can refer to be unwanted (Merton, 1936; Healy, 2012).

The advantages of digital transformation are enormous as pointed out by many authors (Kittipanya-Ngam and Tan, 2020; He et al., 2020; Tan, 2023; Bughin et al., 2018; Li and Tan, 2019; Strange et al., 2022). Digital transformation enables firms to improve the visibility and accuracy of materials throughout the global supply chain and enhance the capability to provide real-time customer support and service customisation. However, digital transformation also has a dark side. Digital technologies and platforms consume vast amount energy, Bohnsack et al. (2022) pointed that one of the unintended consequences of digital transformation is the destruction of sustainable value. Digital transformation also can lead to increased complexity and fragmentation in the supply chain. For example, firms adopt a variety of technologies to digitalise the traditional methods of operations. Without coordination,
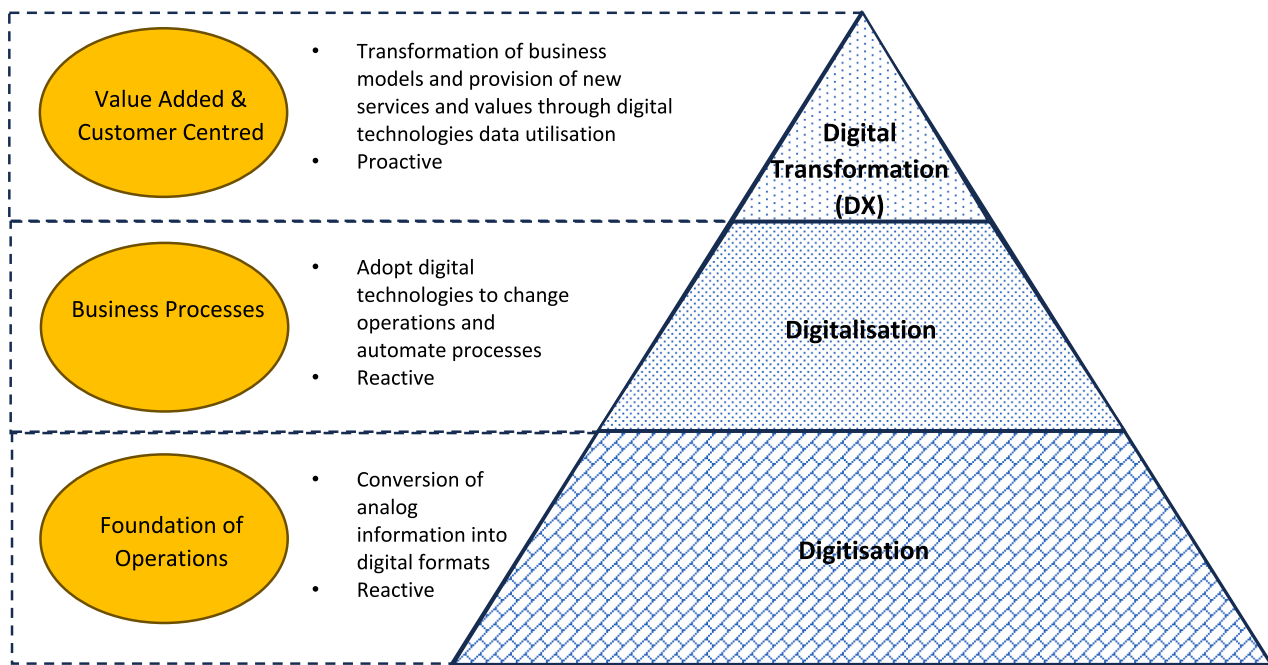
Fig. 1. Digitization, digitalisation, and digital transformation.

firms in a supply network may commission various different technologies which often don't integrate easily, hence can lead to a more complex overall system.

Various authors have examined the unintended consequences or dark side of digitalisation (Table 1 provides a taxonomy table summarising the recent studies). Trittin-Ulbrich et al. (2021) examine a variety of unexpected negative implications of digitalisation in firms, public organisations and NGOs. One of their findings showed that through social media certain organisations could yield more power over public discourse than any other actor in society at the moment. Waldron (2023) pointed out the unexpected drawback, such as technical debt and process inefficiencies, have creating gaps in firms' business processes and

costing valuable time and resources. Bohnsack et al. (2022) highlighted the perverse results of firms using digitalisation to address the sustainable development, which actually make it worse at certain point as power hungry digital technologies usually consumed more energy. Mosch et al. (2021) show that digital transformation transforms value creation processes and subsequently affects relationships and power structures in supply chains. They found out that digital transformation shifts power toward the actor who is more dominant prior to its advent, refining the common belief that service digitalisation favours downstream firms. Hence, existing literature points out two types of unintended consequences i.e. the unexpected drawback and perverse consequence. Collectively, the growing body of literature underscores

Table 1
Studies related to the dark side of digital transformation.

Author(s)	Year	Topic / focus	Geographic context	Key themes	Relevance to dark side of digital transformation
Tech Herfrica	2025	Digital skill-building for rural women	Africa	Gender inclusion, rural empowerment, digital literacy	Highlights digital gender divide and access inequities
Tan, K.H.	2023	Digitalisation for supply chain resilience	Asia / Global	Supply chain, digital transformation, risk mitigation	Raises issues around over-dependence on digital infrastructure
Waldron, R.	2023	Unintended consequences of digital transformation	Global	Ethics, disruption, socio-organizational impacts	Directly critiques harmful side-effects of digital initiatives
Kirchhofer et al.	2023	Digital circular economy and sustainability	Europe / Global	Environment, social outcomes, economic impact	Mixed impacts; questions sustainability claims of digital circular economy
Long, T.	2023	Social aspects of circular economy	Europe	Policy, social equity, circular economy	Highlights neglect of social justice in digital environmental strategies
Manshoven et al.	2025	Digital technologies in the textile sector	Europe	Circular economy, environmental sustainability	Points to sector-specific sustainability challenges and unintended impacts
Mlambo-Ngcuka & Albrectsen	2020	COVID-19 and digital gender divide	Global South focus	Digital exclusion, gender equity, pandemic impacts	Warns of deepening digital divides under crisis conditions
Trittin-Ulbrich et al.	2021	Critical perspectives on digitalisation	Theoretical / Global	Power, inequality, ethical critique	Provides a foundational framework for analysing digital harms critically
Verbeke & Hutzschenreuter	2021	Digital globalisation and its downsides	Global	Power asymmetry, control, economic disparity	Identifies exploitative potential in cross-border digital integration
Healy, T.	2012	Unintended consequences of technology	Theoretical	Historical foresight, ethics, complexity	Early warning on risks of technological progress
Bohnsack et al. (Eds.)	2022	Digitalisation and sustainability (book)	Global	Sustainability, innovation, risk trade-offs	Emphasises both promise and perils of digital tech for sustainable development
Mosch et al.	2021	Power dynamics in digital servitization	Europe (industrial sector)	Supply chain, servitization, dependency	Reveals risks of control and exploitation through digital services
Reuter et al.	2021	Sustainability in digital age	Global	Sustainability, ethical challenges, systems impact	Combines multiple case studies showing varied unintended outcomes

the importance of examining the unintended consequences of digital transformation, one that anticipates co-evolutionary shifts and longer-term disruptions within firms and supply chain ecosystems.

2.2. Unintended consequences of DX in the circular economy context

Many studies have widely acknowledged that DX is a powerful enabler of circular economy principles, particularly through technologies like IoT, big data analytics, digital twins, and blockchain. Liu et al. (2022) systematically analysed 174 studies, identifying 13 key digital functions that empower CE strategies—they pointed out that the theoretical mechanisms linking DX and CE remain underdeveloped, with integration gaps persisting at operational levels. Kirchhofer et al. (2023) argue that sustainability impacts of digital CE initiatives (such as emphasising technical resource efficiency) often overlook rebound effects, social equity implications, or potentially adverse economic outcomes including increased energy use and data governance issues. For example, the rollout of digital product passports under EU policy frameworks, although aimed at supporting traceability, may inadvertently elevate cybersecurity risks, require costly IT infrastructure upgrades, and threaten low-skilled jobs. This is echo by a point raised by Reuter et al. (2021) which highlighted that digital interventions, despite positive sustainability intent may trigger greenwashing, privacy breaches, or new forms of social harm.

Moreover, the rapid digitalisation of CE introduces both opportunities and risks for promoting equality, diversity and inclusivity (EDI). It is widely known that EDI-aligned DX initiatives can empower marginalized groups: for instance, community programs refurbishing electronics to build skills foster inclusion, while women-centric digital literacy schemes (like Tech Herfrica) enhance participation in circular systems—and even job creation (Tech Herfrica (2025)). Conversely, digital divides i.e. gender-based disparities in access and digital skills can reinforce existing inequities (Mlambo-Ngcuka and Albrectsen, 2020). Moreover, risks of unintended negative outcomes (e.g. data privacy breaches, job displacement in low-skilled sectors where inclusion disproportionately benefits more powerful actors) remain underexplored within CE discourse (Long, 2023). Manshoven et al. (2025) examine EU textile recycling policies and find that while landfill bans and green financing incentives drive recycling uptake, they can result in unintended side effects such as waste dumping, loophole exploitation, or behavioral shifts driven by policy design rather than sustainability goals. These findings underscore the need for systemic, context-aware analyses of the "second-order" effects—not just the primary benefits—of digital transformation in sustainable circular economy contexts.

2.3. Digital transformation impact on supply chain power and structure

Digital Transformation enables firms (especially traditional manufacturing SMEs) to tap into the global market and reaching out to vast potential customers that are inaccessible to them before. Digitalisation allows SMEs to receive and respond to sale enquires faster. For example, to rapidly ramp-up invoices for customers in the far corner of the world. During digital transformation, manufacturing SMEs need to acquire critical resources and relax various constraints in order to facilitate collaboration and trust across supply chain and organizational boundaries. This, in turn, will lead to a structural change in the power relationship in the traditional supply chain ecosystem. Many researchers have pointed out that digital transformation enables firms to shift their business models from product-centric to user-centric. The drawback of this is the change of critical resources as firms move toward more data-centric business models.

Mosch et al. (2021) pointed out that gaining control over emerging critical resources can have unintentional consequences, such as the formation of novel dependencies. For example, the move to foster closer end-users relationships may rock the power base of traditional manufacturing firms and trigger a change of supply chain structure and

interdependencies. Pham and Stack (2018) pointed out how John Deere was able to use its open platform MyJohnDeere to obtain control over end-user data and reinforced its dominant market position. Hence, the unintended benefit of digital transformation for downstream firms (such as John Deere) is that they can maintain strategic relationships with customers and better access to their data. The perverse drawback for upstream component manufacturers who are far away from the end users is the diminishing of the assorted power source in the digitalised supply chains and being side-lined by the increasing importance of software solutions (Porter and Heppelmann, 2015). For example, Tesla possess the critical autonomous driving software know-how and good access to end-users, indirectly shrinking the power of the upstream suppliers in the electric vehicle supply chain.

From the globalisation perspective, Verbeke and Hutzschenreuter (2021) point out that global digitalisation can have unintended macro effects and firms will continue to encounter significant challenges when trying to deploy their digital assets internationally. In term of business-to-business (B2B) relationships, Gligor et al. (2021) pointed out that new digital technologies (AI, blockchain, etc.) play an important role in shaping and transforming the way business partners interact. However, the dark side effects (inhibit collaborative creativity, reduce trust and relationship bond) are manifested in B2B relationships.

3. Research methodology

The study of the unintended consequences of digital transformation has relatively little theoretical background (Bohnsack et al., 2022; Trittin-Ulbrich et al., 2021). Thus, in order to gain more insights into the issue, a series of empirical case studies were carried out. The aim of the case study was to understand the challenges and causes of unforeseen consequences of digital transformation in SMEs.

More specifically, the objective was to understand how best to mitigate unintended consequences. In comparison to alternative methodologies like modelling and survey or action research, the multi-case study approach can provide more depth in understanding the unintended consequences (Saari et al., 2024; Karlsen and Engert, 2023; Tuni et al., 2023). Coughlan and Coghlan (2002) pointed out that while action research provides profound insights into particular organizational settings, multi-case studies can encapsulate a broader spectrum of real-world phenomena, offering richer and more diverse perspectives. Additionally, case studies facilitate the exploration of the multifaceted nature of digitalisation, allowing researchers to illuminate both technical and social dimensions within SMEs' supply chains. This is particularly pertinent in examining intricate matters such as the unintended consequences of digital transformation, where the interaction among digital technology, digital talent, supply chain configuration, and industry contexts play significant roles.

The quantity of cases in a multiple case study is not inherently a quality criterion; rather, it should contain ample rich and divergent data to support theory building. Eisenhardt (1989) posits that 4–10 cases are required to develop a theory (although it is not a strict rule). Yin (1984) also stresses the important of choosing samples with a range of variance to meet research requirements. A series of case studies with four Japanese SMEs was conducted in this research. In order to enrich the data for building theory via case studies, researchers normally select cases using replication rather than sampling logic (Done et al., 2011; Pagell and Wu, 2009). Thus, it is vital to select cases that provide the best opportunities to learn and extend theory. Multiple cases in each category enable replication, which is vital for building a generalizable theory (Eisenhardt, 1989).

In Japan, SMEs are defined by the Small and Medium Enterprise Basic Act based on the type of industry, capital size, and number of employees. The criteria are between the range of 50 to 300 million yen in capital size, and with 50 to 300 employees. The sample for this study is drawn from a group of SMEs located in in the Kitakyushu City, known as a City of Manufacturing in Japan. One of the authors in this paper has

established a consortium of 45 SMEs in the city. The consortium provided a platform for the authors to gain access to SMEs/managers who are best informed about the issues being researched. This consortium maintains close collaborative relationships with the author's university. These firms have actively engaged in university-led seminars and workshops related to digital innovation and technology adoption. The selection of cases is based on purposive sampling, with participating firms identified through voluntary involvement of their chief executive officers (CEOs), who expressed a strong interest in supporting academic research. These CEOs are not only open to collaboration but are also active in promoting knowledge transfer between academia and industry. This setting provides a rich context for exploring innovation practices in SMEs, as the firms demonstrate both openness to new ideas and a commitment to university–industry engagement.

The sampling process involved two stages. Initially 7 SMEs were considered, and a meeting was organised for participants and researchers to get to know each other and explore the research objectives in more depth. The subsample was further reduced to 4 SMEs after the first dinner gathering through the exclusion of firms that were unable to meet the researchers' interview and site visit timeline. The willingness to cooperate for detailed discussion for such a delicate research topic is crucial for generating in-depth data for the study. The variety in the cases was a research design strategy chosen to increase the external validity of the study's findings, and to assure that the findings were generalizable and not specific to any one type of business or market (Yin, 1984). Synopses of the four firms are provided in Table 2.

3.1. Data collection

The interviews were conducted in June 2023. All interviews were conducted face-to-face in companies (either in the office on the go or meeting room) and lasted about 90–120 min. A semi-structured interview format was adopted. The manager/CEOs that we interviewed were the most knowledgeable informants given the scope of our study, and the concentration of decision-making authority in SMEs. The interview questions covered the firm background, digitalisation strategy and efforts so far, digital transformation achievement and performance, challenges faced in digital transformation, and the unforeseen impacts. Informal chats also took place with other front-line staff when the interviewers were conducting field observations (see Table 3). Field notes were taken throughout the visits. Various vignettes on unintended consequences of digital transformation were collected.

Table 2
Case background.

Cases	Primary business and activities	Headquarter	Interviewee position	Interview/ visit duration (mins)
A	Hydraulic equipment:- Software solutions for Visual and image inspection,	Kitakyushu, Japan	CEO	120
B	Spatial production:- Deploying digital technologies, AI to enhance the construction industry SDGs	Kitakyushu, Japan	CEO	120
C	System integrator:- Software, IT infrastructure and operational support	Kitakyushu, Japan	CEO	90
D	Healthcare home:- Dementia care, Care home, Multifunctional home	Kitakyushu, Japan	Manager	100

Table 3
Interview instrument.

Semi-structured questions	Informal chats/field observations
General Information • Firm background, history, # of employees, products, customers Digitalisation strategy and efforts, • Motivation, digital technologies, implementation, supply chain. DX achievement and performance, • Support achievement of growth, customer satisfaction, value added, business model Challenges faced in DX • Talent, resources, capabilities The unforeseen impacts • What intended and undesired consequences you have encountered?	• Working environment, • Working conditions • Working methods of a worker • Digital technology usage • Integration of technology and work • Worker emotion • Customer appreciation • New kind of errors

3.2. Data analysis

The researchers also check out the participated firms' websites for relevant cases, news, and reports. To avoid researcher bias in data collection and analysis, visits to case study sites were conducted in pairs; this allowed the case to be viewed from different perspectives. Since one of the researchers is native Japanese speakers, it will be convenient for the interviews to be conducted by their first language. Hand-written notes were also taken where appropriate. Each transcript can then be reviewed to compare the observation between the interviewers. The collected data were analysed through a systematic approach of three phrases: data reduction, coding, and data display (Locke, 2001). This study followed the methodology outlined by Miles and Huberman (1984) to identify and analyse the key themes within the data. Furthermore, a cross-case approach was utilized to explore and describe these themes, enabling a deeper understanding of the phenomena across various firm contexts and enhancing the generalizability of the findings.

4. Findings and discussion

The digital revolution offers Japanese SMEs several opportunities despite challenges in the digital transformation journey. Interviewees in all four cases pointed out that digitalisation can increase productivity, lower operating costs, and improve customer experience. For instance, digital revolution offers Case B to step up networking and collaboration capabilities and develop an agile business model in the construction industry. By leveraging digital technologies such as social media, video conferencing, augmented and virtual reality (AR/VR), and AI-powered platforms, Case B is actively promoting gender inclusion in the traditionally male-dominated construction industry. These tools enable more flexible, remote, and accessible forms of participation for women. For instance, AI technologies allow women to contribute to design, planning, and project management roles from home, reducing the need for physical presence on construction sites—an environment that often poses cultural, physical, or logistical barriers. AR/VR technologies further support inclusion by offering immersive training and virtual site walkthroughs, equipping women with technical skills without the constraints of on-site work. Through these innovations, Case B supports progress toward the United Nations Sustainable Development Goal (SDG) 5. Specifically, this aligns with SDG 5's emphasis on increasing women's participation and leadership in economic sectors where they are underrepresented.

For Case A, artificial intelligence can assist them in automating tedious processes and improving business decisions based on data

analytics. So much so, Case A is capable to capitalise on AI to spin off a new business unit providing software solutions for visual and image inspection. By integrating clinical information, knowledge management tools and decision support, digital transformation enabled Case D to deliver more systematic and high-quality care. Case D capitalises on digital technology for real-time patient monitoring and data analytics to deliver proactive and targeted care to dementia patients. Digital transformation gives Case C increased operational efficiency. For example, Case C utilises digital technologies to consolidate manual processes and reduce overhead costs by integrating with back-office systems to speeding up processes and decision making. Other gains include fewer errors via automating delivery processes and product updates and enhance capabilities in managing multiple product variants and inventory.

A wide range of potential important unintended consequences were identified in the analysis, some representing vulnerabilities of digital transformation, but some are opportunities that can be exploited if recognized. While these consequences present challenges, they are changes that cannot and should not be either avoided or underestimated. From the analysis, the four main unintended consequence themes emerged from the case studies were high digital talent cost, digital power concentration, data standardisation: increased complexity. In the following sections, each theme will be explored in more in-depth.

4.1. High digital talent cost

To stay competitive in today's global market, reducing operating costs and creating new business values for customers are the top priority of many SMEs. However, SMEs' workers' knowledge and skills in AI, data analytics, and process automation will be critical in the digital transformation journey. Hence, all four cases frequently demand specialized expertise in domains like AI, cybersecurity, and data science. Getting the workers with the exact skills and experience required can prove exceedingly challenging, given the relatively limited pool of experts in these fields. As the digital technologies landscape are rapidly changing, Cases A, B, C and D need to constantly develop reskill strategies in order to have the right capability, size and shape of the worker digital dexterity. One of the undesirable outcomes of digital talent development or upskilling is that digitally talented workers have an easy job exit option as they can count on plenty of job opportunities in the market. Hence, the unintended drawback of digital transformation is the endless cycle of upskilling of workers digital capabilities which stretches SMEs' resources to limit.

4.2. Digital power concentration

Data, vast amount of real-time data and customer data is needed to understand and create high value-proposition services for customers. Thereby, Case A pursuing a digital servitisation strategy (AI software solution) is confronted with changing digital power, as they shifted from largely product-centric (hydraulic) to user-centric software solution models. Yet, attempts to gain control over emerging critical resources (access to potential customers) create novel dependencies on powerful IT suppliers such as Google for marketing and explore potential new customers. Oliveira et al. (2021) posits *digital power* as the potential difference in the power imbalance that a supplier may encounter in relation to service providers when performing similar functions in value chains. For powerful MNCs (such as Google or Microsoft) with high degree of digitised value chains, the intermediation of product and market information can be a relevant source of power over their networks (Coe and Yeung, 2015). For Case A, digitalisation supports direct access and interactions with final consumers as well as providing new venues to create value for global customers. At one hand, digitalisation allows SMEs to bypass intermediaries to reach final customers. However, the unintended consequences of that are digital power imbalance i.

e. increasing reliance on powerful IT suppliers for marketing and market access.

4.3. Data standardisation

The rapid pace at which digital transformation initiatives were rolled out and the variety of data to be captured created unintended consequences that Cases C and D struggling to comply. Case C manager pointed out that data standardisation does not eliminate the possibility of variation. Instead, its aims are to simplify processes and ensure consistency, thereby maximizing the benefits of digitalisation. For Case D, there is no standardisation form to capture patient data as each treatment for dementia patient is potentially unique. Hence, costing valuable time and resources in complying with the Ministry of Health requirements. The process of data standardisation can be demanding and slow, often plagued by coordination issues and delayed benefits, which impede progress. Additionally, ensuring the quality of data standards and managing the costly process of their development and maintenance present ongoing challenges.

4.4. Increased complexity

Digital transformation necessitates considerable financial investment and time, thus entailing inherent risks and uncertainties. Managers in all four cases emphasised the importance of ongoing planning for technology upgrades, organizational capabilities enhancement, and talent development. Implementing digital transformation in regulated industries like healthcare (Case D) presents its own set of challenges. One of the perverse consequences of digital transformation is that it can lead to increased complexity and fragmentation. It is well understood that vast number of operations and customer data need to be captured in order to create values and provide better services. To comply with regulation, Case D is capturing and generating more data than ever. Due to lack of data standardisation, workers are finding it difficult to capture and store data or to apply these vast amounts of data to support decision making and optimize their patients' experiences. Workers are creating workarounds for siloed data, and upkeep of multiple databases is placing a burden on IT resources. For many workers, the promise of technology to improve efficiency and streamline operations hasn't yet come true. Case D workers were yet to see the benefits to be gained from more data capture. What is obvious is digital transformation incurs additional resources for data entry and capture.

The findings show that unintended consequences are part and parcel of digital transformation. But this does not mean that SMEs should abandon operations digitalisation to minimize uncertainty. Unintended consequences can be mitigated, largely through better operations knowledge and understanding of the uncertainties, but not eliminated. Fig. 2 illustrates the intended and unintended consequences and the interplay with desirable and undesirable outcomes of digital transformation. The 2 × 2 matrix has four quadrants of consequences: (a) intended consequences that are desirable; (b) Intended consequences that are undesirable; (c) unintended consequence that are desirable; and (d) unintended consequences that are undesirable. "Unintended" and "undesirable" are related but distinct concepts. Unintended consequences refer to outcomes that were not the original goals or expectations of an action. They can be either positive or negative. Undesirable consequences, on the other hand, specifically refer to negative outcomes or effects that are unwanted or harmful (Merton, 1936; Healy, 2012). In Fig. 2, above the water line are observable/foreseeable consequences while below the water line are hidden/unforeseeable consequences. Hence, the iceberg matrix can help SMEs discover the intended and unintended consequences that underlie digital transformation.

The primary hindrance to accurately understanding the unintended consequences of digital transformation lies in SMEs current level of knowledge. Despite its challenges, this study firmly believe that SME managers must take responsibility and acknowledge the unintended
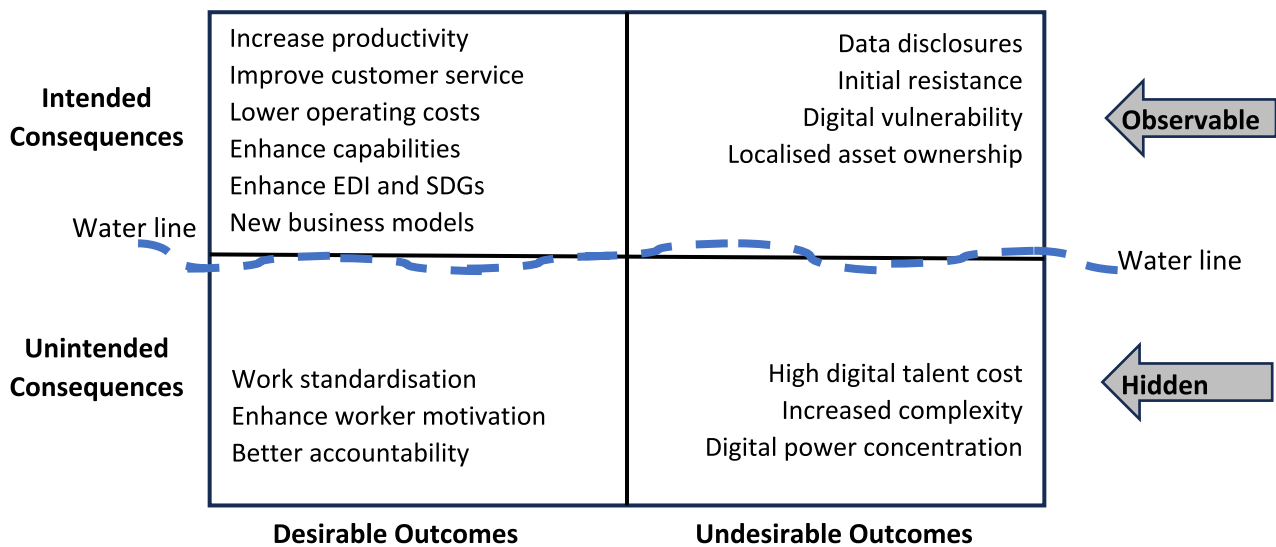
	Desirable Outcomes	**Undesirable Outcomes**

Fig. 2. Intended and unintended consequences Iceberg.

consequences. To mitigate the unintended consequences, we propose that SME practitioners embrace a proactive approach i.e. prioritise consideration of unintended consequences from the outset. Managers must carry out an in-depth analysis of unintended consequences in every step of the digitalisation journey. Senior SME executives can effectively contribute to the prevention and management of unintended consequences by actively demonstrating the significance of these matters through personal involvement and strong leadership.

SMEs can mitigate unintended consequences by deepening their knowledge of digital transformation and increase control of the desirable outcomes. It is important for practitioners to understand that an effective way to mitigate the unintended consequences begins with the awareness of the desirable and undesirable outcomes. This study has proposed an intended and unintended consequences iceberg (see Fig. 2) by which SME practitioners can better account for observable and hidden outcomes. This study contends that not all unintended consequences should be viewed as vulnerabilities; rather, some present exploitable opportunities.

This study reinforces and extends previous findings by highlighting how digitalisation, while widely recognized as a catalyst for circular economy (CE) practices, can also generate unintended consequences that mirror concerns raised in earlier research—such as rebound effects, social exclusion, and increased energy consumption (Ren et al., 2019; George et al., 2023; Karakaya and Sriwannawit, 2015). In particular, our findings support existing literature that cautions against overly optimistic views of digital transformation in sustainability contexts. While there is general alignment with past work, certain discrepancies, particularly regarding the social justice implications of digital CE interventions, warrant further investigation. These findings underscore the need for a more critical and inclusive framework to assess the socio-environmental impacts of digitalisation in circular transitions.

5. Conclusion

Successful digital transformation very much hinges less on how firms use digital and more on how they become digital. Digital transformation is a long-term effort to rewire how firms continuously improve its operations and value propositions to customers. Managers should understand that managing the interconnectivity of technologies and solutions is key to digital transformation success. Surprisingly, many SMEs mainly see the positive benefits of digital transformation and underestimate the unintended consequences of digitisation, the potential changes in power structure and supply chain relationships, and, perhaps most of all, the

scale of the perverse consequences bearing down on them. Yet, existing studies present little and incomplete views on the unintended consequences of digital transformation.

The four main unintended consequence themes emerged from the case studies were high digital talent cost, digital power concentration, data standardisation, and increased complexity. The main challenge in comprehending the unintended consequences of digital transformation is our existing knowledge base. This research proposes an iceberg model of intended and unintended consequences, enabling SME practitioners to consider both visible and hidden outcomes more effectively. Furthermore, the study argues that not all unintended consequences should be seen as vulnerabilities; instead, some can be leveraged as opportunities. For example, although data standardisation can be a gruelling and slow process initially, but in a longer term once the data is standardised, it can be enriched, consolidated, and subsequently activated to generate valuable, actionable insights.

This research provides a significant contribution to knowledge to digitalisation, digital transformation, and supply chain relationship related research. Our findings extend existing literature by identifying underexplored unintended consequences of digital transformation in circular economy contexts, particularly in relation to social equity, digital inclusion, and organizational readiness. These aspects have received limited attention in prior studies, and our work adds depth by providing a more nuanced understanding of the risks and tensions that can arise. This paper contributes to both theory building and provide important practical implications by: (a) enriching the conceptual understanding of the unintended consequences of digital transformation; (b) providing managers important insights and practical advice to mitigate unintended consequences; and (c) delivering actionable insights for public sectors in developing citizen-centric governance models that maximize social capital and minimize environmental impact. It is worth stating that digital technologies are so ubiquitous that avoidance is not feasible, but often SMEs have the freedom to make choice of their adoption.

Though only limited cases, but this research provides important insights and external validity of the empirical data, thus enable the findings to be generalizable to firms to a wider context such as in other developed and emerging economies. Another limitation of this study is that the findings are based solely on the Japanese SMEs. Divergences may arise in other countries due to differences in digital technology adoption and economic frameworks. Additionally, some scholars posit that differences in digital cultures exist across nations. Consequently, a promising avenue for future research lies in conducting a comparative

analysis of unintended consequences, considering the influences of country and culture. Moreover, future research could examine the unintended consequences of DX in the public sectors and make a comparison study with this research. In the present research, we didn't differentiate fully digitalised value chains from the partially digitised ones. We assumed that all Japanese SMEs has the same level of digitalisation. Hence, future research can explore the different level of undesirable consequences at different degree of digitalised value chains. Moreover, further investigations into the role of digital technologies such as artificial intelligence (AI), blockchain, and the Internet of Things (IoT) in both mitigating and potentially exacerbating unintended consequences within circular economy practices would offer valuable insights. Future studies could explore how these technologies influence sustainability outcomes, social equity, data privacy, and economic impacts, helping to identify strategies to harness their benefits while minimizing risks.

CRediT authorship contribution statement

Leanne Chung: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Kim Hua Tan:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation. **Osamu Yoshie:** Writing – review & editing, Supervision, Methodology, Investigation, Data curation.

Declaration of competing interest

The authors declare that there are no conflicts of interest associated with this research. All three authors actively participated in the case studies conducted in Japan and contributed fully to the development of this paper.

Data availability

The data that has been used is confidential.

References

Behl, A., Singh, R., Pereira, V., Laker, B., 2023. Analysis of industry 4.0 and circular economy enablers: a step towards resilient sustainable operations management. Technol. Forecast. Soc. Chang. 189, 122363.
Bohnsack, R., Bidmon, C.M., Pinkse, J. (Eds.), 2022. Wiley 599–602.
Bughin, J., Catlin, T., Hirt, M., Willmott, P., 2018. Why digital strategies fail. McKinsey Q. 1, 61–75.
Coe, N.M., Yeung, H.W.C., 2015. Global Production Networks: Theorizing Economic Development in an Interconnected World. Oxford University Press.
Coughlan, D., Coghlan, D., 2002. Action research for operations management. Int. J. Oper. Prod. Manage. 22 (2), 220–240. https://doi.org/10.1108/01409170210418464.
Davenport, T.H., Westerman, G., 2018. Why so many high-profile digital transformations fail. Harv. Bus. Rev. 9 (4), 15.
Deere, John, 2023. Tami Hedgren Explains Digital Transformation. https://www.deere.com/en/stories/featured/tami-hedgren-explains-digital-transformation/ (Accessed on 23 June 2023).
Done, A., Voss, C., Rytter, N.G., 2011. Best practice interventions: short-term impact and long-term outcomes. J. Oper. Manag. 29 (5), 500–513.
Eisenhardt, K.M., 1989. Building theories from case study research. Acad. Manage. Rev. 14 (4), 532–550.
George, R., Lin, B.C., Doran, J., Allwood, J.M., 2023. The unintended consequences of digitalisation in the circular economy: a systematic review. Resour. Conserv. Recycl. 189, 106818.
Gligor, D.M., Pillai, K.G., Golgeci, I., 2021. Theorizing the dark side of business-to-business relationships in the era of AI, big data, and blockchain. J. Bus. Res. 133, 79–88.
He, Q., Meadows, M., Angwin, D., Gomes, E., Child, J., 2020. Strategic alliance research in the era of digital transformation: perspectives on future research. Br. J. Manag. 31 (3), 589–617.
Healy, T., 2012. The Unanticipated Consequences of Technology. In: Nanotechnology: Ethical And Social Implications, pp. 155–173.
Karakaya, E., Sriwannawit, P., 2015. Barriers to the adoption of sustainable technologies: a review of empirical studies. Ecol. Econ. 117, 160–182.
Karlsen, H.T., Engert, S., 2023. Digital platforms in the circular economy: a multi-case study approach in the construction and textile industries. Bus. Strat. Environ. 32 (6), 2636–2650. https://doi.org/10.1002/bse.3202.

Kirchhofer, A., Rizos, V., Walter, K., 2023. The sustainability impact of a digital circular economy: systematic review of environmental, social and economic outcomes. Curr. Opin. Environ. Sustain. 61, 101251. https://doi.org/10.1016/j.cosust.2022.101251.
Kittipanya-Ngam, P., Tan, K.H., 2020. A framework for food supply chain digitalisation: lessons from Thailand. Prod. Plan. Control. 31 (2–3), 158–172.
Li, H.H.J.K., Tan, K.H., 2019. Transformative innovation: turning commoditised products into radically high-valued products. J. Intell. Manuf. 30, 2645–2658.
Liu, Q., Trevisan, A.H., Yang, M., Mascarenhas, J., 2022. A framework of digital technologies for the circular economy: digital functions and mechanisms. Bus. Strateg. Environ. 31 (5), 2171–2192. https://doi.org/10.1002/bse.3015.
Locke, K., 2001. Grounded Theory in Management Research. Sage, London.
Long, T., 2023. 'By forgetting the social dimension, is the Circular Economy missing an opportunity?' EDHECVOX. https://www.edhec.edu/en/research-and-faculty/edhec-vox/by-forgetting-social-dimension-is-the-circular-economy-missing-an-opportunity?utm_source=chatgpt.com.
Manshoven, S., Smeets, A., Christis, M., Duhoux, T., Lingås, D., Grossi, F., Mortensen, L. F., Clarke, J., 2025. Textiles and the Environment – The Role of Digital Technologies in Europe's Circular Economy. In: European Topic Centre on Circular Economy (ETC/CE) report file:///C:/Users/lizkht/Downloads/ETC%20CE%20Textiles%20and%20the%20environment%202025_for%20website.pdf Accessed on 23 June 2025.
Merton, R.K., 1936. The unanticipated consequences of purposive social action. Am. Sociol. Rev. 1, 894–904.
Miles, M.B., Huberman, A.M., 1984. Qualitative data analysis: a sourcebook of new methods. In: qualitative data analysis: a sourcebook of new methods, p. 263.
Mlambo-Ngcuka, P., Albrectsen, A.-B., 2020. We cannot allow COVID-19 to reinforce the digital gender divide. https://www.unwomen.org/en/news/stories/2020/5/op-ed-ed-phumzile-covid-19-and-the-digital-gender-divide?utm_source=chatgpt.com.
Mosch, P., Schweikl, S., Obermaier, R., 2021. Trapped in the supply chain? Digital servitization and power relations in the case of an industrial technology supplier. Int. J. Prod. Econ. 236, 108141.
Oliveira, L., Fleury, A., Fleury, M.T., 2021. Digital power: value chain upgrading in an age of digitization. Int. Bus. Rev. 30 (6), 101850.
Pagell, M., Wu, Z., 2009. Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars. J. Supply Chain Manag. 45 (2), 37–56.
Pham, X., Stack, M., 2018. How data analytics is transforming agriculture. Bus. Horiz. 61 (1), 125–133.
Porter, Michael E., Heppelmann, James E., 2015. How smart, connected products are transformation companies. Harv. Bus. Rev. 93 (10), 96–114.
Ren, S., Zhang, Y., Liu, Z., Sakao, T., Huisingh, D., Almeida, C.M.V.B., 2019. A comprehensive review of industrial symbiosis research: theoretical foundations and mainstream research. J. Clean. Prod. 207, 1157–1176.
Reuter, E., Knight, H., Hellemans, I., Portet, A.J., Cappa, F., 2021. Sustainability in the digital age: intended and unintended consequences of digital technologies for sustainable development. Bus. Strateg. Environ. 31 (2), 599–683.
Saari, A., Huiskonen, J., Pynnönen, M., Salmi, T., 2024. Circular economy matrix guiding manufacturing industry companies towards circularity: a multiple-case study. J. Clean. Prod. 434, 140812. https://doi.org/10.1016/j.jclepro.2023.140812.
Selznick, P., 1948. Foundations of the theory of organization. Am. Sociol. Rev. 25–35.
Strange, R., Chen, L., Fleury, M.T.L., 2022. Digital transformation and international strategies. J. Int. Manag. 28 (4), 100968.
Tan, K., Rae, R., 2009. Uncovering the links between regulation and performance measurement. Int. J. Prod. Econ. 122, 449–457.
Tan, K.H., 2023. Building supply chain resilience with digitalisation. In: ADBI Annual Conference Fostering Resilient Global Supply Chains amid Risk and Uncertainty. Asian Development Bank Institute, Japan (forthcoming).
Tan, K.H., Chung, L., Shi, L., Chiu, A., 2017. Unpacking the indirect effects and consequences of environmental regulation. Int. J. Prod. Econ. 186, 46–54.
Tech Herfrica, 2025. Tech Africa - How Tech Herfica is Developing Rural Women's Skillset in Africa. https://www.techherfrica.org/tech-africa-how-tech-herfica-is-developing-rural-womens-skillset-in-africa/?utm_source=chatgpt.com.
Trittin-Ulbrich, H., Scherer, A.G., Munro, I., Whelan, G., 2021. Exploring the dark and unexpected sides of digitalisation: toward a critical agenda. Organization 28 (1), 8–25.
Tuni, A., Santos, J.L., Chiaroni, D., Garcia-Muiña, F.E., 2023. Risks in circular business model innovation: a cross-industrial case study for composite materials. J. Ind. Ecol. 27 (2), 418–434. https://doi.org/10.1111/jiec.13349.
Verbeke, A., Hutzschenreuter, T., 2021. The dark side of digital globalization. Acad. Manag. Perspect. 35 (4), 606–621.
Waldron, R., 2023. Addressing The Unintended Consequences Of Digital Transformation Initiatives. Forbes. https://www.forbes.com/sites/forbestechcouncil/2023/05/01/addressing-the-unintended-consequences-of-digital-transformation-initiatives/?sh=63b4f7dc1e26 (Accessed on 23 June 2023).
Yasuoka, H., 2023. Digital transformation strategies and issues in local SMEs: issues of strategy and personal data. J. Strat. Manag. Stud. 14 (2), 25–31.
Yin, R.K., 1984. Case Study Research: Design and Methods. Sage, Newbury Park, CA.

Dr Leanne Chung is currently the Director and Academic Lead of International Exchange at the Cardiff Business School. She is a Reader (Associate Professor) in International Business and Management. She has a cross-disciplinary background. Her initial training was in Organizational Psychology in Taiwan and Hong Kong. She then studied for her PhD in International Business and Management at the Judge Business School, University of Cambridge, investigating the transfer of organizational practices from Hong Kong firms to Mainland China. Leanne has extensive university teaching and research experience in

Greater China. Leanne's current research interests are in the fields of international business and business organization. She currently focuses on innovation management in emerging economies, headquarter-subsidiary relationships, and managerial control, with particular reference to Chinese multinational corporations. She has published in high-impact international journals including the Journal of International Business Studies, British Journal of Management, Management International Review, International Journal of Production Economics, International Journal of Operations and Production Management, and Technological Forecasting and Social Change.

Professor Kim Hua Tan is a Professor in Operations and Innovation Management. Prior to this, he was a researcher and teaching assistant at Centre for Strategy and Performance, University of Cambridge. Professor Tan spent many years in industry, before joining academia in 1999. His current research interests are lean management, operations strategy, decision making, and supply chain risk management. Professor Tan has published a book called 'Winning Decisions: Translating Business Strategy into Action Plans,' and numerous articles in academic journals such as Decision Sciences, International Journal of Operations and Production Management, International Journal of Production Economics, International Journal of Innovation Management, and others

Professor Osamu Yoshie is a Professor with Waseda University, Japan, where he is the Director of the Institute for Global Strategies on Industry-Academia Fusion (IGSIAF). He also worked at FX Palo Alto Laboratory, USA, and GMD (Currently, Fraunhofer), Germany. His research interests include computer vision, augmented reality, artificial intelligence, industrial IoT, and community analysis and synthesis. He was a recipient of many awards from professional research societies, such as the Society of Instrument and Control Engineers (SICE), the Institute of Electrical Engineers (IEE) Japan, the Society of Plant Engineers Japan, Japan Industrial Management Association, etc. He is a fellow of IEE Japan