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Leveraging digital data to facilitate circular control in the aftermarket – experiences from an international manufacturing firm

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Abstract

Purpose – Growing research attention has been given to both the circular economy and digitalisation in accounting research in recent years, but there are few studies exploring how digital tools are used to develop, analyse and respond to information for circular decision-making in industrial organisations. Therefore, this paper addresses how the data from digital technologies are leveraged in the aftermarket of an industrial firm for circular control.

Design/methodology/approach – The paper develops an analytical framework that is then used to frame the findings through a single case study of an international heavy equipment manufacturer for circular control.

Findings – The case provides examples of how digital technologies are used for circular control, framed within the analytical model as the key contribution. The study illustrates the different ways through which the accounting information from such technologies supports the service marketing function through circular control and the types of controls needed for this.

Practical implications – Managers in large industrial organisations should ensure customer-facing staff have adequate digital competences and knowledge of circular products and services for marketing, product design improvements and material recovery that can help decrease costs and improve customer satisfaction. The digital systems need to be integrated with upstream and downstream partners.

Social implications – Understanding the transition towards increasingly circular product-service systems in industrial firms is important for current and future generations.

Originality/value – The originality lies in providing an empirical example of how digital technologies can be used to facilitate circular control and support the service marketing function in the aftermarket of an industrial firm.

Keywords Circular economy, Decision-making, Digital technologies, Product-service systems, Sustainability control systems

Paper type Research paper

1. Introduction

The circular economy is “an economic system in which resource input and waste, emission, and energy leakages are minimised by cycling, extending, intensifying, and dematerialising material and energy loops [which] can be achieved through digitalisation, servitisation,

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sharing solutions, long-lasting product design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling" (Geissdoerfer *et al.*, 2020, p. 3). Circular economy practices are alternatives to the more traditional linear business models of the past (see Russell *et al.*, 2017). They promote broader conceptualisations of environmental and economic value for industrial firms and their customers by slowing, narrowing or closing resource loops (see Geissdoerfer *et al.*, 2017). For manufacturing firms, product service systems (PSS) are central for greater circularity in the supply chain (see, e.g. Johnstone, 2024; Kühl *et al.*, 2020; Yang *et al.*, 2018). PSS regards the addition of services such as equipment leasing, maintenance and disposal, as well as product/component replacement or refurbishment (Spring and Aruajo, 2017) in addition to their core products. Notwithstanding, successful PSS for circularity require timely information exchange between industrial firms and other upstream or downstream partners for the control of resource flows (see Johnstone, 2024; Svensson and Funck, 2019).

Circular economy principles have clear implications for systems of accounting and control in large industrial firms. Put simply, sustainability controls are implemented in organisations to connect strategy with operations by guiding, monitoring and motivating employee behaviour for a particular control problem (see Crutzen *et al.*, 2017; Guenther *et al.*, 2016; Johnstone, 2019), in this case, improved circularity. For sustainability control systems, accounting tools provide decision makers with environmental and economic performance information, which affects the design and use of subsequent controls (see Guenther *et al.*, 2016). This means that there are two main roles of management control for sustainability issues, including circularity, as described by Svensson and Funck (2019, p. 392), referring to the works of mainstream management control scholars (e.g. Anthony *et al.*, 2014; Chenhall, 2003): "(1) to develop, analyse and respond to information for decision-making situations; and (2) to guide employee behaviour in the desired direction to ensure that employees' behaviour and decisions are consistent with the organization's strategy and objectives"; in order words, control for both decision-making and behavioural alignment functions.

Empirical research into how controls are used for decision-making and behavioural alignment in circular transitions is nevertheless limited (Cheffi *et al.*, 2023; Crutzen *et al.*, 2017; Nadeem *et al.*, 2018; Scarpellini *et al.*, 2020). This is especially the case for the empirical context of the aftermarket in manufacturing firms (i.e. the market for spare parts, components, etc.), whereby various services can be offered to control the recycling, refurbishing, remanufacturing, repairing and maintenance of industrial products (see Yang *et al.*, 2018). Such a context, however, entails challenges given that it requires information exchange between upstream/downstream partners and focal industrial firms to make decisions that help narrow (i.e. process and design efficiencies), slow (i.e. product life extension) and/or close (i.e. material reuse and/or return) resource loops (see Bocken and Ritala, 2021; Johnstone, 2024). Examples of circular controls, therefore, include key performance indicators (KPIs) related to recycling rates, material reuse or action plans for future products and services offered, among others (see Johnstone, 2024; Svensson and Funck, 2019).

Notwithstanding the importance of control in industrial organisations for the circular economy, there remains little research in this empirical context. Of the studies that do exist in terms of circular accounting and control, the focus has been on the macro-level of inter-organisational networks or communities through metrics for waste generation, material consumption and incentive schemes (e.g. Du Rietz, 2022; Jørgensen *et al.*, 2023). There have also been studies framing circularity as a strategic vehicle for legitimation through CSR reports (e.g. Olczak *et al.*, 2023). Meanwhile, of the few studies centred on the organisation, the focus is on the types of management controls used to support circular transitions. Cheffi *et al.* (2023) find that the ethical leadership of SME managers and the use of management control systems are positively associated with circular economy practices. Moreover, Svensson and Funck (2019) find the need for strong cultural and planning controls, particularly in the earlier product life-cycle stage of circular transitions. Meanwhile, there currently remains no empirical research on how the decision-making function of control supports circularity, which is especially important for PSS in industrial firms. This is where the current study sets to fill a gap.

Alongside any economic system such as that of the circular economy, accounting information is necessary to support control decisions such as those described above. For PSS in industrial firms, it is particularly important to use such information for the qualification of existing products, components and materials and then design circular services that support this (Spring and Araujo, 2017). Here, the data from digital technologies along customer interfaces can be particularly fruitful (see Alcayaga *et al.*, 2019; Geissdoerfer *et al.*, 2020). The benefits of digital technologies for supporting performance management are clear (Jørgensen *et al.*, 2023). This is because digital data provide "feedback-rich systems throughout the product lifetime, facilitating information transparency and process circularity" (Alcayaga *et al.*, 2019, p. 622). For PSS, therefore, digital technologies are used to track materials throughout the supply chain, offer timely services, monitor performance and put numerical values on resource streams (see, e.g. Centobelli *et al.*, 2020; Di Vaio *et al.*, 2023; Jørgensen *et al.*, 2023). These benefits can also be related to control in the aftermarket in terms of supporting circular innovations such as remanufacturing and repairs.

While growing research attention has been given to both the circular economy and digitalisation in accounting research in recent years, there is currently little research that explores how digital tools are used *to develop, analyse and respond to information for circular decision-making* as one function of management control (see also Scarpellini *et al.*, 2020). Additionally, prior circular-control research centred has focused on the type and use of controls for behavioural alignment, especially in product design phases (Svensson and Funck, 2019), rather than on how information is used to support decisions for material recovery in the aftermarket. Therefore, this study aims to better understand how digital technologies are used in an industrial organisation to develop, analyse and respond to information for circular decisions by asking: *How are the data from digital technologies in the aftermarket leveraged by an industrial firm for circular control?* The originality of the paper lies in the research object, namely, the impact of digital technologies on control for circular PSS strategies (i.e. those that extend product life and support material recovery through the services offered). The empirical context is that of the aftermarket division of an international heavy equipment manufacturer, which is considered important given that the prior circularity-control focus is on product development phases (e.g. Svensson and Funck, 2019). It is also important given the increasing recognition of PSS as integral for circular transitions, whereby accounting information from customers and their machines is vital for closing resource loops, as well as product and service innovations (Johnstone, 2024; see also Biswas *et al.*, 2023).

In focusing on the role of digital technologies for circularity, this paper contributes by putting forward an analytical model that offers a structure within which the relationships between digital technologies for control and circularity can be framed (see Miles and Huberman, 1994, p. 18). Additionally, the empirical findings contribute to discussions on sustainability integration (see Gond *et al.*, 2012) and how accounting information (via) digital technologies can support the marketing function of industrial organisations for improved circular performance (see Johnstone, 2024).

The paper begins with a literature review in Section 2 that elaborates on the two purposes of management control and then connects these to circular economy transitions as the strategic control problem, before discussing the role of digital technologies therein. This results in an analytical model connecting control, digitalisation and circularity for, in this case, PSS in an industrial organisation. Thereafter, Section 3 describes the case study and analytical approach, before the findings and discussion are presented in Sections 4 and 5, respectively. The paper concludes in Section 6 by overviewing the research and practical implications of this work.

2. Sustainability control systems and the circular economy

Research into sustainability control systems [1] has been growing in recent years as a response to the increasing institutional demands being placed on organisations to account for and control social and environmental issues in more formalised ways. Sustainability controls (e.g. environmental and social performance indicators, governance structures, codes of conduct, incentive systems, etc.) are important tools used by organisations to translate their strategic sustainability objectives into practice. While formal controls regard the more tangible or visible objectives, governance structures and procedures of organisations, informal controls regard the communication and follow-up pathways between superiors and subordinates [see Pondeville *et al.* (2013) for more examples of this distinction]. Both formal and informal controls are nevertheless part of the formalised control system design to meet particular strategic objectives.

As organisations attempt to integrate sustainability into corporate strategy (see, e.g. Gond *et al.*, 2012), many sustainability control studies use argumentation theories such as legitimacy or stakeholder to elaborate on why top managers design sustainability controls in response to external demands (e.g. Arjaliès and Mundy, 2013; Rodrigue *et al.*, 2013). In doing so, prior studies often emphasise the behavioural effects of control system design by top managers on other employees (e.g. Corsi and Arru, 2021). Management control system frameworks such as Simons (1995) levers of control (e.g. Arjaliès and Mundy, 2013; Beusch *et al.*, 2022) or even Malmi and Brown's (2008) management control system package (e.g. Baker *et al.*, 2018; Crutzen *et al.*, 2017) are often used in such studies to explain and frame not only why but also *what* sustainability controls are designed and implemented to achieve improved sustainability performance. While *systems* (cf. Simons, 1995) entail interdependencies and integration between clusters of control, *packages* (cf. Malmi and Brown, 2008) suggest the independent application of specific controls to achieve improved performance outcomes (see Grabner and Moers, 2013 for an overview). That being said, the application of the levers in sustainability control studies rarely addresses all together (Johnstone, 2019) and thus fails to satisfy Simons' (1995) notion of balance. This suggests that for sustainability, control systems are more often framed as conceptual packages or analytical frameworks in extant studies, rather than theoretical ones.

Adopting the terms used in the above-mentioned frameworks, some key trends can be noted in terms of the types of controls used for sustainability issues based on prior literature. After an initial focus on planning and performance-related controls such as cybernetic or diagnostic controls (e.g. Henri and Journeault, 2010; Ratnatunga and Balachandran, 2009), administrative (e.g. codes of conduct, training programmes and the governance structure of the organisation) and socio-ideological or cultural controls (e.g. visions, symbols and values) are now generally accepted as being (more) important for sustainable performance outcomes in focal organisations (see, e.g. Baker *et al.*, 2018; Crutzen *et al.*, 2017) and supply networks (Spence and Rinaldi, 2014). Johnstone (2018) even bridges these administrative and socio-ideological categories of control by introducing the concept "social control" as especially important for environmental knowledge, communication and commitment within organisations. This is achieved through a corporate culture that promotes education and training of environmental issues. Such sentiments are evident in the limited circular-control studies already mentioned (e.g. Cheffi *et al.*, 2023; Svensson and Funck, 2019). Meanwhile, there is a general lack of studies that address the reward and compensation controls used for sustainable employee behaviours (see Crutzen *et al.*, 2017; Soderstrom *et al.*, 2017).

Notwithstanding the usefulness of management control system frameworks for framing and explaining sustainability control issues, various challenges have been identified. Mainstream management control system frameworks have been critiqued in their inability to deal with the extra-organisational and inter-generational aspects of sustainability (Guenther *et al.*, 2016; Johnstone, 2019). This can also be related to the spatial challenges of circular economies given that extant frameworks take an intra-organisational perspective on control. Another debate regards whether sustainability should be integrated into existing systems of management accounting and control. While Gond *et al.* (2012) imply that the integration of sustainability into corporate strategy along organisational, technical and cognitive dimensions is optimal, which would likely be the case for industrial firms in their quest for circularity, others nuance this claim. In brief, organisational integration regards "how actors and processes are organised around sustainability" (Battaglia *et al.*, 2016, p. 214), technical integration regards how regular activities and systems for financial control are integrated with sustainability purposes for "a common calculability infrastructure" and cognitive integration regard the extent to which "managers" have shared understandings of sustainability (Gond *et al.*, 2012). Notwithstanding, various studies find that having separate sustainability control roles, departments and/or accounting systems is, in fact, necessary to coordinate and control sustainability work, particularly in large industrial organisations (e.g. Corsi and Arru, 2021; Frostenson and Johnstone, 2023; Riccaboni and Leone, 2010). This supports others who have suggested that it is often not accountants and controllers who are implied in the sustainability control work (e.g. Egan and Tweedie, 2018; Rodrigue and Picard, 2022).

2.1 The function of sustainability control for circular transitions

As previously described, the role of management control for, in this case, circularity (see Svensson and Funck, 2019), can be framed along two functions when related to extant definitions of management control (e.g. Anthony *et al.*, 2014; Chenhall, 2003):

- to develop, analyse and respond to information for decision-making; and
- to guide, monitor and motivate employee behaviour that aligns with strategy.

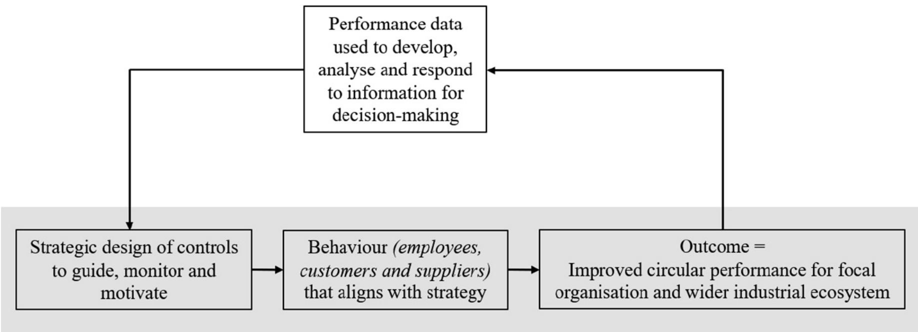

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Figure 1. Connections between the functions of control for circular transitions

Figure 1 relates these functions of control in response to "circularity" (i.e. combined environmental and economic performance) as the control problem. The figure highlights the extant research focus on the formalised design of controls (as formal or informal) at the strategic level by top management and their interaction effects to ensure behavioural alignment for a particular performance outcome (grey shaded area). This behaviour alignment is most often associated with lower-tier employees as the subjects of the controls which are implemented by top managers to reduce individual agency. However, the figure extends prior conceptualisations of intra-organisational control for circular transitions in industrial organisations by incorporating (1) the behaviour of *customers* in the aftermarket for resource recovery and extending product life (see Bocken and Ritala, 2021; Johnstone, 2024) and (2) *other upstream actors* such as suppliers for procurement and logistics functions (ibid.). Hereby, the performance effects of strategically designed controls not only have implications for the focal industrial firm but also for wider circular ecosystems.

Beyond the behavioural alignment function of control, the figure also incorporates the less discussed function of control in terms of how industrial organisations use performance information (from products, customers and suppliers, etc.) to develop, analyse and respond to (future) strategic circular objectives. Specifically, through its focus on how digital technologies are used to develop, analyse and respond to information for circular decision-making (see also Scarpellini *et al.*, 2020), the current study sets to fill a gap as the following sub-section elaborates on.

2.2 The role of digital technologies for circular decision-making

The fourth industrial revolution, within which we now find ourselves in, is changing how companies do business as they integrate digitalisation into their daily activities. When related to the purpose of this study, it is considered increasingly important to know more about the role of digitalisation in facilitating circular control decisions as such research is scarce (Scarpellini *et al.*, 2020).

Digitalisation regards the use of digital technologies such as Big Data, data analytics, the Internet of Things, enterprise resource planning (ERP) systems and digitalised supply chains (see Knudsen, 2020; Kristoffersen *et al.*, 2020) to make "fundamental changes to business operations and business models based on newly acquired knowledge" (Fähndrich, 2023). This helps support the circular strategies of industrial organisations and their wider business networks, for example, by tracking resource and component flows by sharing information throughout the value chain for inter-organisational control (see Carlsson-Wall *et al.*, 2018).

More specifically, Di Vaio *et al.* (2023) emphasise the importance of digital technologies for product and process innovations related to the circular economy in industrial organisations, which may also be important for designing and implementing controls to support such innovations (see, e.g. Svensson and Funck, 2019). Additionally, data analytics are useful for modelling and predictions on downtime and maintenance schedules for industrial products (Porter and Heppelmann, 2014), which are important for planning and performance-related controls. Finally, when related to material recovery and closing resource loops in the aftermarket, the data from connected smart PSS are key to support strategic decisions in industrial firms (Alcayaga *et al.*, 2019).

While qualitative empirical studies on the role of digitalisation for accounting purposes are scarce (Bhimani, 2020), digital technologies have nevertheless been cited as important for new types of information and decision-making processes, and various scholars suggest that such technologies are reshaping accounting and control decisions (see Quattrone, 2016; Appelbaum *et al.*, 2017). Nevertheless, the vastness of digital data entails certain challenges related to its quantity and quality. There is the general sentiment shared by researchers and practitioners that in their rawest form, data are worthless but rather, need to be refined to be made into useful information for accounting and control purposes. Quattrone (2016) furthers that the rationality implicit in analytics as raw data may lead to some irrational decisions being made, and that accountants and managers should aim for reasonable decisions based on this data rather than trusting the data as *the* solution. Others have implied a certain resistance to digitalisation in that the potential of digital technologies has not been realised in practice, and traditional management accounting techniques remain (Fähndrich, 2023).

Notwithstanding these limitations, because of digitalisation, systems and tools that inform decision-making can be brought into non-accounting functions, such as those associated with sustainable or circular strategies related to, for example, material recovery and reuse. Kristoffersen *et al.* (2020) comment that the "digital circular economy" is a "cornerstone of a sustainable society". The data from digital technologies can be translated into useful information for decision-making, helping to address questions such as: "what has happened (descriptive analytics), what will happen (predictive analytics), and what is the optimized solution (prescriptive analytics)" (Appelbaum *et al.*, 2017, p. 29). Such questions are central for the transition of industrial organisations towards increasingly circular strategies, and especially so considering the data that can be shared between various upstream and downstream actors to support such transitions in different areas of business (e.g. circular PSS). Nevertheless, the "extent to which data-driven decision making is used [for accounting and control purposes] remains unclear" (Knudsen, 2020, p. 15). In a review study on the impact of digitalisation on management control, Fähndrich (2023) further emphasises the need for competencies to be developed in terms of "digitalisation know-how" (e.g. through digital education programmes) for actors such as management accountants and controllers to use digital technologies in their daily work.

Overall, digital technologies are increasingly important for decision-making and behavioural alignment as functions of control. The information from digital technologies is especially useful for PSS in industrial organisations. However, we know very little about how the information provided by such technologies is used in practice for, in this case, circular control.

Figure 2 summarises the preceding discussion into an analytical model which frames this research. The figure integrates the two functions of control for circular strategies in the aftermarket as the empirical context, whereby the design of the focal organisation's circular control system is contingent on the connected digital data from other industrial partners (i.e. upstream and downstream actors). These data are considered vital for an industrial firm to develop, analyse and respond to timely information from customers (and their machines)

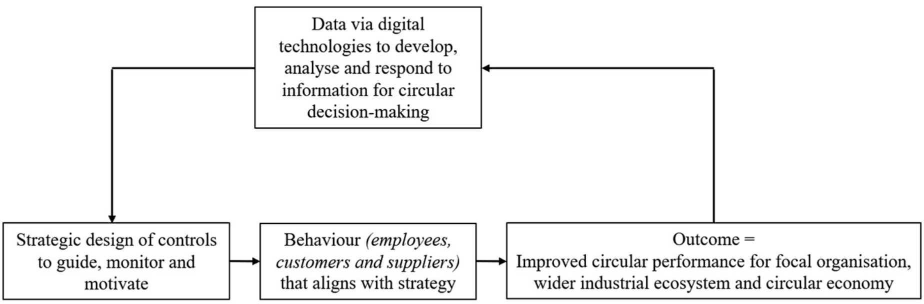

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Figure 2. Leveraging data from digital technologies for circular control in the aftermarket

and are also important to share with suppliers to provide circular service offerings as a form of open innovation (Johnstone, 2024). Therefore, a key contribution of this model is its incorporation of the inter-organisational aspects of control for PSS in an industrial context whereby the behavioural alignment of not only employees but also customers and suppliers are important for circular transitions.

3. Method

Given that research connecting circularity, control and digitalisation is scarce (see Scarpellini *et al.*, 2020), an exploratory single case study of an international manufacturing firm and its strategic focus on circular PSS is adopted for the purpose of this research. Case studies are commonly adopted in accounting research (see Vaivio, 2008) to introduce new perspectives and ideas through exploring real-life contexts (see Stake, 2005). Like many recent sustainability control studies in industrial organisations (e.g. Beusch *et al.*, 2022; Frostenson and Johnstone, 2023), a single case study is useful for this aim. Here, the principle of transferability (Lincoln and Guba, 1985) that is implied. This means that the observations and findings from this case may be transferable to, or connect with, other cases in different contexts through the identification and development of common themes (Parker and Northcott, 2016) that can increase the analytical generalisability of the findings herein through further studies.

3.1 Case selection and data

The case selected for the purpose of this research is that of a large, multinational manufacturer of heavy industrial machinery – Company X. Company X has its headquarters in Europe but operates in 150 countries. Its structure regards five global divisions wherein two relate to the types of products sold and the remaining three focus on the aftermarket as a key revenue generating stream, namely: aftermarket services, components and digital solutions.

Of interest to this study is that Company X has both strategic goals related to digitalisation and circularity through, for example, PSS. As per the visionary footage that included the CEO's message (internal data), Company X has the ambition of 100% circularity by 2030, as well as an explicit mission of driving productivity with customers and partners through digitalisation, automation and electrification. Currently, Company X is transitioning from a more linear, production-based past focusing on bottom-line performance towards top-line growth and other revenue-generating streams such as that of services. The service portfolio has been extended to offer more services that support environmental value propositions, such as electrification, midlife and remanufacturing services. Due to these strategic ambitions, Company X combines digital and circular strategies to manage its PSS and there are currently around 900 digital systems and applications being used by the different divisions.

Access to Company X was gained in late 2022 through two introductory meetings with a senior aftermarket manager at the group level, who was based at one of Company X's main management hubs in the same region as the research institution. Interviews were often mediated through this initial company contact, but also through a snowballing approach as interviewees suggested others to speak to on certain topics. The agreement between the primary contact was for research to be conducted over a six-month period in the aftermarket division. This was extended slightly as access to more interviewees was mediated.

Overall, 15 semi-structured interviews with employees in service, sustainability and IT positions were conducted. Given the focus on circularity and digitalisation, speaking to those working in the aftermarket division proved extremely useful because the customer returns of products and/or components to Company X are key to realising circular ambitions. The information coming in (e.g. product/component tracing, machine performativity, etc.) was often linked to some digital tool that helped inform decision-making. In this sense, the key decision makers and "controllers" for circular PSS, while in the group level of the aftermarket division and sustainability department, were not in positions titled as management accountants or controllers as is often the case for control issues pertaining to sustainability (cf. Egan and Tweedie, 2018; Rodrigue and Picard, 2022). Furthermore, while some of these interviews were conducted in person at the two local facilities where seven visits were made in total (five to the first site and two to the second), most were conducted online (see Appendix 1). This, however, was not posed as a disadvantage but rather as providing new research opportunities (de Villiers *et al.*, 2021; Molinari and de Villiers, 2021). This is because employees within the aftermarket division of Company X were located around the world, meaning that the interviewer was able to speak to key individuals within the company (e.g. regional presidents and customer centre managers) that otherwise would not have been possible (ibid.).

Beyond the interviews, other primary data included a tour of the factory to see the heavy machines sold and a visit to the warranty and quality department to understand how product and process improvements were made at Company X in relation to customer claims. During these visits, questions were asked to support case understanding of their circular products and services. Additionally, internal video footage of the CEO's strategic sustainability ambitions was shared and there were also numerous informal talks with employees at lunch meetings when on site, as well as before and after official interview times both online and on site. In addition to interview transcripts, notes were taken both during and after these encounters and provided a broader understanding of the case company and how it works both generally and, more specifically, in relation to the research aim.

The primary data were supplemented by the following secondary data: information from the company website, annual sustainability reports (2020, 2021 and 2022) and internal documents (i.e. the service portfolio and the strategic vision of the service council), as well as external legislations and guidelines (i.e. the corporate sustainability reporting directive [CSRD/2022/2464/EU], EU Battery Directive [2006/66/EC] and New Battery Regulation [2023/1542]). Importantly, the secondary data provided contextualisation to certain aspects (e.g. the circular strategic ambitions, types of products and services offered and their relation to these, etc.). This aided understanding for the researcher during official interview times, as well as supported backgrounding in the research findings. Therefore, both types of data sources allowed for rich material for the aim of this study.

As the study was initially conceptualised as exploratory in the sense of knowing more about the role of digital technologies for (mainly) internal strategic decision-making related to circularity (wherein the different roles and types of control were more inductively formed), the initial focus of the interview guides was operationalised around understanding how Company X operates in the aftermarket as the empirical context and the use of digital technologies therein for supporting strategic internal product and process improvements. As is often the case in qualitative research, in later reiterations of the interview guide, which were tailored to particular interviewees, the questions became more explicit on the connections between the role of digital technologies for facilitating circular decisions (Hall and Messner, 2018). The central role of upstream and downstream actors for circularity also became clear, meaning that the empirical work and analysis occurred concurrently to the literature review and refinement the analytical model in an abductive fashion (see Alvesson and Sköldberg, 2017). Through such a design, the researcher's understandings and analyses were incorporated into each draft of the interview guide as the research developed (see

Parker and Northcott, 2016). Appendix 2 offers a sample of interview questions asked for the purpose of this research that are connected in various ways to the guiding analytical model and key concepts.

3.2 Data analysis procedure

Given the exploratory nature of this study, the analytical model presented earlier in the study was later used to structure the findings considering the questions embedded into Figure 3 when analysing the transcripts and field notes as the main data sources.

As a first step, relevant quotations from the transcripts were highlighted and then grouped under preliminary codes (e.g. services, inventory management, product innovations, etc.). These initial codes were subsequently grouped under higher-order themes that characterised the role and challenges of various digital technologies for control and circularity (e.g. PSS for circularity; digital systems for feedback, decision-making and control; and, digital challenges of current systems). The secondary themes were refined again considering the analytical model to structure the connections between digital technologies for control and circularity (see Miles and Huberman, 1994, p. 18). This was achieved by making notes directly in the analytical framework as the analysis occurred, resulting in the production of Figure 4, which summarises the findings. Notably, Figure 4 was inspired by Luft and Shields (2003) mapping guidelines for theory-consistent empirical management accounting research whereby key relationships from the data were framed considering both the analytical model and the empirical findings to illustrate, particularly, the moderating relationships that arose (see also Johnstone, 2018).

Working backwards from the analytical model, the next step was to present the findings of the case in a narrative form (i.e. description of the case) that began with an overall case background description in more detail related to the research aim. This was followed by a structure that presented the findings from the transcripts and secondary data that roughly followed the analytical model; that is, with sub-headings operationalised around the two functions of control (i.e. digital technologies for the decision-making and then behavioural alignment aspects of control). An additional sub-heading was added that elaborated on the challenges related to this based on the research purpose. The summary model (Figure 4) was then presented at the end of the findings section, serving as a link for the reader between the key findings framed within the analytical model that are later taken up in the following analysis section in connection to prior control research.

4. Findings

4.1 Case background

Company X is an international manufacturer of heavy industry equipment for mining and construction customers, with a reputation for selling low volume, highly customised, long-

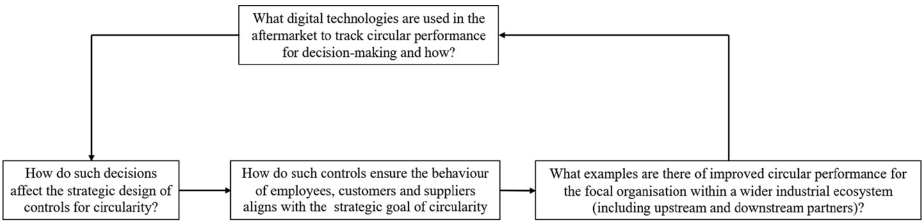

Figure 3. Incorporation of key questions that informed the inductive analysis of the findings in relation to the analytical model

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lasting products. It operates on the market with few direct competitors, and even though other suppliers may be able to provide certain components, some parts and technical competences are specific to Company X's machines. This helps contribute to customer lock-in to ensure the longevity of machines through buying the additional services that Company X offers.

With its headquarters in Europe, Company X's strategy has been increasingly influenced by sustainability issues in recent years due to various external factors (e.g. sustainable development goals, CSRD and customer pressures, among others). When related to circularity, Company X has had a key electrification strategy since 2011, partly the result of the EU's Battery Directive (2006/66/EC) and New Battery Regulation (2023/1542), which are part of the European Green Deal that aims to reduce environmental impact and European autonomy through closing resource loops. This strategy involves Company X providing batteries and chargers as services (i.e. whereby Company X retains ownership of the assets), as well as the replacement of diesel engines with electric ones. Currently, however, Company X works with an upstream partner for recycling batteries.

Other services have also been adapted to increasingly incorporate circular elements. While the midlife services are sold with the aim of incorporating more recycled or remanufactured components when machines are serviced, the remanufacturing service is sold through service agreements whereby customers return parts to be recycled and replaced with remanufactured components. Together, such services help Company X narrow, close and slow resource loops in collaboration with its customers as downstream partners.

Already mentioned is the key strategic ambition of Company X for increased circularity. There are strategic objectives related to its electrification programme as well as emission targets related to Scope 1 and 2 production processes and energy, as well as Scope 3 supplier and customer emissions as per CSRD requirements. Company X also has internal service targets related to circularity in the form of KPIs for customer service sales staff to have half of all machines sold on the three main service agreements that support circularity (i.e. electrification, midlife and remanufacturing services). This is considered beneficial not only for Company X's strategic ambition to be (more) circular but also for increasing the value of the products sold to customers by providing solutions over their lifecycles by focusing on the "total cost of ownership" (Sust2):

> Service matters because we start with selling a machine. But, this machine has a life. And, we need to make sure that this machine performs during its life and that's a big part of our business. So, we make sure that the customer has a successful experience of our products. And, then that is also how we gain more business. So, service really becomes more like circular, because we need to take care of the machine (S9).

Another important strategy for providing timely services in the aftermarket relates to the use of digital technologies to translate customer data into actionable insights. Digital solutions constitutes one of the three core divisions in the aftermarket that helps support the circular ambitions of Company X. The use of digital technologies is considered especially important for circularity by knowing precisely how customers use their machines (i.e. operational hours, downtime, peak usage etc.):

> When I think about think about smart services, if you're in circularity, you're able to kind of preempt. That you can give the customer what they want. Yeah, maybe a remanufactured component. It doesn't have to be brand new. (Sust1)

It is precisely how the data from digital technologies are used for circular controls, as well as the challenges this poses for Company X that are presented in the following sub-sections which are operationalised around the two interconnected functions of control.

4.2 Digital technologies for the decision-making function of control

To provide more services and better control for circularity within the aftermarket, the potential of "information" from digital technologies is changing how accounting decisions are being made:

> We're moving away from having people with knowledge towards [. . .] storing that knowledge [. . .] as central information and not person related. This is the big change. [. . .] There is a move from isolated information to having it as global information that everybody can use (S9).

Digital systems are especially important for Company X and its international presence to get remote data from customers and their machines. For circularity, these data are used to support product innovations (i.e. to make internal product and process improvements) and provide better solutions for customers (i.e. to ensure material/product longevity and closing resource loops through the services offered):

> Getting data is a fantastic opportunity to know more. Imagine that we were only doing the capital equipment and not the service, right? You send out the machines and you don't have a clue what happened, right? You need that feedback loop regarding what is not working and through this, you build the relationship with the customer (S5).

Data are also used for accounting information related to Scope 3 emissions as previously described.

Company X currently uses various types of digital systems to obtain data from the aftermarket; data which are then translated into information for internal circular decisions. One such example is that of remote diagnostics whereby telemetry is used to "follow the machines" (S1) and thereby understand their functionality and remote operations for future performance improvements. It is the digital technical team that has the job of "making sense of the data from sensors through a control system" (S7).

On the service side, there is a customer relationship management (CRM) system that stores data related to "service and maintenance" (S10). These data are then analysed by customer centre staff to make decisions as to when (scheduled) maintenance needs to be undertaken and if/when/what circular services should be offered. Similarly, there is a product lifecycle module system that is also used for the "preventative maintenance" of (parts of) machines (S1):

> We need to be able to say to a customer 'okay, maybe this is a little old, have you thought about midlife?' Or you could even say 'this diesel machine is becoming outdated, how about we do a battery conversion?' (Sust1).

As noted, those working in customer service centres play an important role in "convincing customers that sharing data from their machines [when both leased and bought] is good for them and Company X" (S7). A recent aim has been to develop a digital application that engages customers in sharing their data, leaving feedback and/or giving reviews (S1). This moves beyond the focus of other digital technologies on metrics. Beyond this, digital tracing is also cited as important for inventory management in the supply chain as well as for offering "quality and efficiency to the customer" (S5).

Of relevance to decision-making for Company X that extends beyond service sales in the aftermarket, has been the roll out of a company-wide ERP system since 2019. This was based on the desire to obtain a "standardised" approach to operational data that can lead to increasingly centralised accounting decisions within the company, as well as for the harmonisation of marketing (i.e. selling products or services) and accounting decisions (i.e. running costs) in the aftermarket:

> We are essentially heading to service design and if it's built in, helps us to calculate that because customers in the future or even now don't really want to buy without knowing 'how much is this going to cost me in running costs? How much can I budget on this equipment being available?' Maybe they don't need the absolute top end equipment. Maybe they can afford to have two or three in their fleet of second-tier machinery, and if one of them breaks down there still got two more to use (S1).

Through such a system, feedback for both the customers and Company X extends beyond financial considerations into circular ones in terms of the sustainability outcomes of the machines and the potential for offering circular services such as batteries:

> We know how much emissions come from our machines because we're in charge of reducing those. And, we're the only ones that can actually say, 'okay, if this is a battery or this is, you know, there would be X less amount of emissions'. So, we create battery machines which are amazing for our customers, they love it! (Sust1)

Here, the knowledge generated from the data is used in research and development teams to innovate the products and services offered. It is also used by customer service centres to market and thus sell circular services that help meet different KPIs.

Given that circularity is all about maintaining and cycling material loops, the transition in Company X towards PSS and getting (more) information from customers in the aftermarket via the data provided by the various digital technologies mentioned is key for informed internal decision-making and controls. This leads to better operational performance for both Company X and the customer as downstream partners vital for the company's circular transitions.

At the same time, service agreements that support circularity also entail risk:

> We fix the machines. We do everything for the customer. So, this is a risky business, right? Because how do you know what it will cost in the end to maintain this contract? And, we want this signed up front. So, it's a huge risk for us to lose money or even lose the contract because we don't know our machines [. . .] What it costs to maintain the machine, you know, all these factors you need to consider [. . .] how do you actually know the true figures? The total cost of ownership. How do we know what a certain machine costs, over life-time? This is where we need the data. But, the data are not perfect (S4).

In the following, an elaboration on how Company X uses the accounting information (via digital technologies) from customer data for control purposes is given.

4.3 Information use for the behavioural alignment function of control

Information translated from customer data is important for Company X to make further improvements in PSS innovations related to circularity. It is also important for pre-empting customer needs through timely service offerings, as well as for tracking performance outcomes related to, for example, Scope 3 emissions and digital tracing for supply chain purposes. This implies that the data from the digital technologies are refined to ensure that the behaviour of employees, customers and suppliers supports Company X's circular – and even digital – strategic ambitions.

More specifically, the raw data from the machines are used by Company X to "understand performance, benchmark [the] machines' capabilities against other competitors [. . .] and to offer future services that predict maintenance" (S4). These data appear to be mainly used by the digital technical team, service centre staff and engineers for circular product and service innovations; that is, rather than employees with financial accounting or management control backgrounds. Nevertheless, the translation of data into accounting information is vital for streamlining resources, which can support circular transitions. This is achieved through providing tailored solutions for customers based on planning and performance controls:

> For a certain machine in a certain site, why should we change all the parts in a certain number of hours? If we have the data, then we can have the service when it needs to be serviced, not just because it passed 250 h [. . .] that's the worst case around the world for about 3% of our customers. But, the rest? Parts can be replaced every 500 h (S4).

Another function of the data relates to intra-organisational control in terms of reporting KPIs. As indicated, having data from the machines is necessary for inventory management and planning service intervals to reduce waste. The data also help signal whether the performance-related targets of the various divisions are on track. These targets are tied to specific individuals (normally service centre managers) and included in their respective bonus systems.

Beyond this internal focus, data from the machines are also necessary for planning inter-organisational control:

> [. . .] planning the supplier parts and knowing what is needed. [. . .] if you do proper planning, you can make sure that you source the right things and there is less waste. And, having access to more digital data [. . .] when I think of the supply chain, is important. Another part [for circularity] is looking at regional sourcing, because if we are sourcing closer to the customer, and can plan for this, we also reduce carbon emissions. We reduce a lot of waste in that whole process and the thought with this, is the circular economy (S5).

4.4 Challenges of digital technologies for circular control

While generally, getting more data from the machines in the aftermarket is useful for customer service sales and operational performance decisions, it also comes with certain challenges that require subsequent controls to be implemented. One common concern comes down to the extent of data from the machines that are not used for analytical insights related to circular PSS. In some instances, the more traditional face-to-face channels between service centre staff/technicians and customers prevail in guiding internal PSS decisions and innovations: "We should know our own machines. We should be the experts on our machines. But, sometimes the customer knows more about our machines than we do (S4)". One reason put forward for this weakness was the "novelty" and vastness of circular data related to PSS. Another factor raised was the historical background of Company X as a traditional heavy equipment manufacturer, making it subject to a lot of "unknowns" in emerging areas such as circularity and digitalisation:

> You know, the areas like automation and electrification that people think are cool areas and data is a cool area [. . .] But, then when you need to manage this data nobody want to manage it. Because it's too much information and they don't know how to manage. (S8)

As a result, some senior level managers commented on the need for certain administrative controls to ensure that staff have the right technical competences on not only the machines being sold, but on the digital systems being used and the circular services being offered. Computing competence was even noted by one interviewee as a key recruitment criterion for work in the aftermarket division (S6).

Another major concern regards getting the data from the machines. Infrastructural and connectivity issues at geographically remote areas where the machines are situated depend on "customers' Wi-Fi and networks" (S4). This means that it is not always possible to get the necessary data in real time to offer circular services and/or maintenance when needed. This time lag further raises issues for inter-organisational inventory management throughout the supply chain for circular service provision.

Additionally, when compared to companies of similar sizes, the sheer number of digital applications and systems at Company X is almost double at around 900 applications (S1). Difficulties are noted by those working in the IT department (e.g. license management and IT security). Yet, those individuals do not have the decision-making power (i.e. mandate) to streamline existing systems and/or integrate them with existing accounting functions.

> We have so many systems or applications for different and similar things in different departments that, I think that the problem that we have today, in many areas, is the lack of transparency, which makes it really difficult for the management to take the right decisions (IT1).

This can also lead to key decision makers "zooming in on one system at a time" (S4), which may make it difficult to gain an overall understanding of what is happening within the company regarding circularity. As a result, many interviewees signal a desire for some form of system architecture or "roadmap" in the coming years.

Indeed, a groupwide rollout of the ERP system has begun, with the hope of streamlining some functions and there are even two specialist teams in the IT department working directly with this. Yet, this only raised another interesting dimension when related to the economic costs of digital accounting systems for control purposes, where the IT support function bears the brunt:

> If you have a lot of manual processes like we have in service and you move to digital tools, your IT costs will increase, right? But hopefully you remove some operational costs, but those don't show up on my account [cross functional IT department support]. So, it looks like my accounts are steadily increasing, and that's one problem that we are not able to have (IT1).

A final problem relates to the differentiation between global and local systems. Traditionally, the local service centres around the world have been able to design and use their own adapted digital systems to get customer information as it was "a question of the global solution not keeping up" (S5). However, through its roll out of the ERP and CRM systems previously mentioned, there has been an increasing move towards global digital systems in recent years. The very creation of the digital solutions division as part of the aftermarket back in 2018 also signals the importance of obtaining, refining and streamlining digital data for circular control purposes that extend beyond the focal company with customer and supplier performance benefits:

> That's why the division was established [. . .] to establish more specific roles then people working more with digital technologies and solutions. Our service centers are around the world as are the product offerings. We need the digital resources in place (S3).

4.5 Summary of findings

Figure 4 presents the findings in the analytical model that frames this work to illustrate the types of digital technologies used in Company X to obtain data for circular decision-making in the aftermarket, as well as how these relate to the different functions of control. The findings reveal that data from such technologies were analysed by non-accountants in the aftermarket (e.g. digital technical teams, service centre staff, product engineers and R&D teams, as well as senior managers) to monitor, motivate and guide certain behaviours within the focal company and its industrial ecosystem. This led to economic and environmental performance benefits for the company and (primarily) its customers. However, the success of obtaining digital data for circular control purposes through smart, connected systems in the aftermarket was, in this instance, negatively affected by infrastructural challenges and the degree of technical integration between the digital systems. This is reflected in the dashed lines in the figure. A more detailed discussion of these findings and how they connect to extant sustainability control literature is taken up in the analysis section that follows.

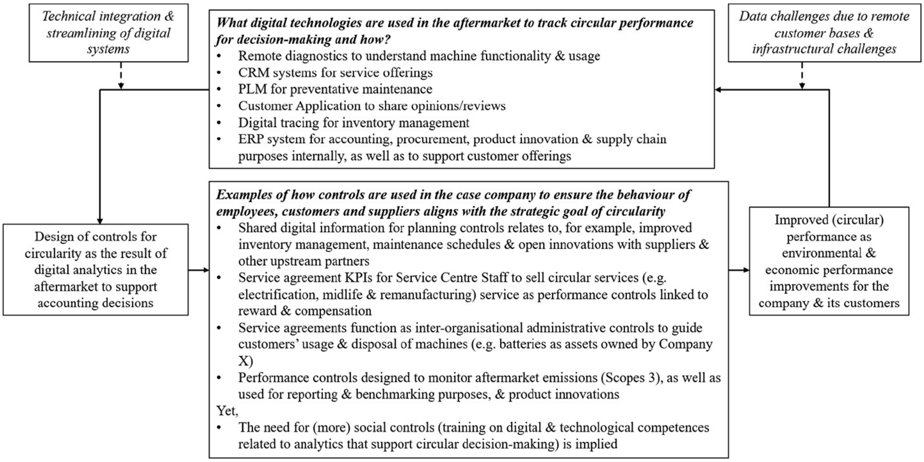

Figure 4.
Overview of the findings in relation to the analytical model

Source: Author's own creation

5. Discussion

The use of accounting information for improved circular business model controls is necessary to monitor products and processes both within industrial companies and throughout their supply chains. However, the connections between accounting decisions for improved circularity in the aftermarket have rarely been explicated. Even less empirical studies have been conducted on the use of digital technologies for aftermarket information to improve an industrial firm's circular service offerings and thus circular performance from a control perspective. The recent empirical circular accounting and control research focuses on circular ecosystems at community levels (e.g. Du Rietz, 2022; Jørgensen *et al.*, 2023) or in product development phases (e.g. Svensson and Funck, 2019). Additionally, the emerging digitalisation-accounting research (e.g. Appelbaum *et al.*, 2017; Knudsen, 2020) is notably silent when it comes to issues of sustainability and/or circular control.

Based on these research gaps, the findings of this paper respond to recent calls (e.g. Nadeem *et al.*, 2018; Scarpellini *et al.*, 2020) by offering insights into how information can be leveraged from digital technologies to facilitate circularity in the aftermarket of an industrial firm. Similar to prior works (e.g. Johnstone, 2024), the development of PSS for circular control is put forward as an important strategy, among others, adopted by industrial firms in their circular transitions. The findings also suggest that the data from various digital technologies in the case of the company are being used in different ways to support decision-making and behavioural alignment in the aftermarket as the two, interrelated functions of control, important for circularity (see Svensson and Funck, 2019). In the analysis that follows, the findings of this case are elaborated and discussed considering prior sustainability control research. These are structured around the two functions of control.

5.1 The use of digital technologies for circular product service systems decisions

The case highlights the mainly quantitative use of the data coming in from various digital technologies to support circular decision-making and PSS innovations by tracking performance. Although the data are not information, and other challenges remain (e.g. data capture in remote areas and data volume and overlap in multiple systems), the incoming metrics are nevertheless key for a variety of circular control purposes in Company X and used by various individuals (e.g. digital technical team, service centre staff and product engineers).

For example, remote diagnostics and telemetry are used to understand the performativity of machines when in operation by customers, and are thus important for emission reporting, product innovations and circular service offerings. Further, digital tracing systems are used for inventory management that extends throughout the supply chain to promote closed resource loops. One interesting finding was the attempts being made to integrate more qualitative customer feedback through the customer app(lication). This indicates a subtle move away the "numerical" data of the digital technologies towards the technologies being used for customers to express opinions, knowledge and reviews of the machines. Here, the "qualification" aspects of circular PSS as described by Spring and Aruajo (2017) in the wider service marketing literature, requires the right information from and about customer machines for circular innovations and decisions.

While such findings align with the prior benefits noted from digital technologies in terms of, for example, putting values on resource streams and timely service provision (see Centobelli *et al.*, 2020; Jørgensen *et al.*, 2023), such technologies also require customer input, i.e. in terms of sharing data for the company's descriptive, predictive and prescriptive analytics (see Appelbaum *et al.*, 2017). Particularly, the predictive and prescriptive analytics are highlighted given that the case company uses the data from certain digital technologies to both prevent and pre-empt customer product and service needs related to circularity. Here, decisions are made either in terms of the product itself through innovations or by foreseeing customer needs (i.e. for both product and service offerings). Both product innovations and service offerings, as part of the PSS, aim to reduce machine downtime by slowing or closing resource loops (e.g. by replacing components with remanufactured parts). Nevertheless, getting the right data from the customer entails certain challenges, not least because customers are expected to be business partners but also because of the infrastructural and connectivity issues noted in the case.

Such findings reinforce the importance of accounting information for the circular service marketing functions for manufacturing firms. In such instances, it is the service centre staff who are using the "accounting" information for marketing purposes that support customer satisfaction through environmental and economic performance benefits. This finding illustrates the role of non-accountants and controllers in circular decision-making (see Egan and Tweedie, 2018; Rodrigue and Picard, 2022) but extends this beyond "sustainability managers" into other functions or departments such as service centre staff, digital teams and product engineers. Such individuals appear to be doing the "accounting and control" work by translating customer data into actionable insights that support circularity as the control problem. This finding also supports studies that suggest the organisational decoupling between "sustainability" and "financial" structures is a reality of many large companies (Corsi and Arru, 2021; Frostenson and Johnstone, 2023; Riccaboni and Leone, 2010).

Notwithstanding the evident benefits noted above through obtaining information from digital technologies in the aftermarket of the case company, the multitude of digital systems present also relates to the technical integration dimension posed by Gond *et al.* (2012). It appears that the case company does not exhibit a great degree of technical integration between the systems used for accounting and circular PSS functions; that is, systems for financial accounting purposes and circular control remain primarily decoupled. There is also an issue relating to the streamlining of such systems. The vast digital infrastructure, coupled with the historical autonomy of service centres to adopt their own preferred localised accounting systems (see Goretzki *et al.*, 2018), means a significant degree of overlap between systems (in terms of different systems performing the same function). That being said, the groupwide rollout of the ERP system initiated in 2019 attempted to redress this. It appears that standardised digital systems – as opposed to decentralised ones – through the homogenisation of digital infrastructures is a real objective. There is the perceived need in the company to centralise data for effective decisions that relate not only to circular PSS but also for other procurement, inventory and financial decisions, among others.

5.2 Types of controls for behavioural alignment in circular product service systems

Beyond the decision-making function of control, the findings also indicate something about the types of controls used for the behavioural alignment of Company X's employees, customers, suppliers and even other upstream partners (e.g. battery recycling facilities), whereby the information coming from digital technologies plays an important role. While the analysis thus far indicates that the role of information (via digital data) for circular decisions is related to both product and service innovations, there are also clear links to the role of such information on the design of performance, planning and social controls that is now elaborated.

5.2.1 Controls for planning and performance. The sharing of digital information with suppliers and customers on machine performativity has clear implications for circular planning and performance-related controls that deal with both product(ion) and service aspects.

Along the service side, there appears to be a tactical use of planning controls in terms of inventory management and maintenance schedules with suppliers and customers for the case company. This is also relayed through the types of service agreements sold at customer-service centre interfaces that are linked to discrete KPIs on selling service agreements that focus on circularity. Although performance-related bonuses appear to be reserved for service centre managers at the tactical level, the selling of electrification, midlife and remanufacturing service agreements are key for *all* centre service staff. Having services sold on such agreements are integral for measuring and monitoring the resources of Company X, which supports resource recovery and product life extension as the circular goals of PSS. It is also deemed important for customer satisfaction to have productive, environmentally efficient machines.

Additionally, through the service agreements sold, Company X can control the usage and disposal of machines and parts, which is necessary for its circular strategy. As the electrification service example highlights, Company X retains ownership of the battery and charging infrastructure and then leases them to customers to support their own electrification strategies. This means that resource recovery and maintenance are embedded into the electrification agreement as a type of inter-organisational administrative control in that the agreement is a formalised policy used to slow, narrow or close resource loops; imperative for circular performance. That being said, Company X currently does not have the internal capability to recycle its batteries and works in collaboration with an upstream partner to do this.

Along the production side, the information from digital technologies is used for internal and external control purposes, again related to performance through product innovations that support, for example, emissions reductions by machine optimisation. It is also used internally for reporting Scope 3 emissions. Here, the performance of Company X's machines can be benchmarked against its main competitors, again illustrating how accounting information indirectly supports the marketing function in PSS through superior performance that can be marketed to its customers both through capital sales, but also in the aftermarket.

5.2.3 Human aspects of social control along customer interfaces. Notwithstanding the focus on the more tangible planning and performance-related controls illustrated above, which are manifested through service agreements as a form of administrative control, the findings also imply the importance of customer-facing staff competences. Such "competences" can be broadly captured under what have previously been termed social controls (Johnstone, 2018) as will later be explained. These competences relate not only to the digital skills required of aftermarket staff but also an awareness of the types of services offered in relation to Company X's circular ambitions and different customers' needs.

Already discussed is the role of the information from digital technologies for descriptive, predictive and prescriptive analytics (see Appelbaum *et al.*, 2017), but the human element of such analytics remain especially important for circular PSS in the case organisation in that it is the service centre staff or digital team, etc., that make sense of the raw data. In this sense, the data are leveraged only to the extent that the employee using it can leverage the data, and this appears to require certain competences. As Quattrone (2016) emphasises, decision makers should not blindly trust data as the solution, but rather use the data in a way that supports rational decision-making in the wider context of the firm and in this case, its wider industrial ecosystem that includes customers and suppliers as business partners. Hereby, the human elements of control are important for circularity (see also Cheffi *et al.*, 2023; Svensson and Funck, 2019).

Considering the findings of this study, the service centre and technical staff are required to have training in digital systems and analytics to be able to offer circular customer service offerings. Such a point is emphasised by Fähndrich (2023) who highlights the need for digital education programmes for the daily work of management controllers in the digital era. From a marketing stance, the service centre staff and technicians are also require technical knowledge and/or training in terms of how the products and parts are designed to be circular (e.g. replacements with remanufactured parts or electric machines). This suggests that the expertise or knowledge embedded within individual employees on both digital know-how (Fähndrich, 2023) and circular issues (hereby related to the products and services themselves) may be prerequisite for circular control in manufacturing firms, functioning as a type of social control (see Johnstone, 2018).

According to Johnstone (2018), social control regards various properties on the micro-level of the individual employee for improved environmental sustainability as the control problem. These properties are knowledge about environmental issues, commitment to environmental issues, communication about environmental issues and an organisational culture that promotes the training of environmental issues (ibid.). Most of these can be seen in the case example in that service centre staff and technicians are ultimately required to have knowledge on circular products and services, be committed to selling or servicing products or services connected to these issues (connected to their KPIs) and be able to communicate the benefits of circular products or services to customers through their knowledge of such. The case also illustrates the need for more training (e.g. digital technologies and analytics) as a form of administrative control to support such knowledge, commitment and communication of circular products. This, again, would serve as a type of control to support the marketing function of the company to achieve not only internal KPIs related to circular service agreement sales but also for KPIs related to customer satisfaction and waste management as indirect performance effects.

5.2.3 Networked approaches for circular control. Perhaps one of the most interesting aspects of the analytical model presented in this study comes down to not only its connection between the two functions of control but also its inclusion of other industrial partners for improved circularity as the control problem. This inter-organisational orientation of circular control, in this case for the PSS of a focal heavy equipment manufacturer, integrates the design and use of controls for the behavioural alignment of customers, suppliers and other industrial partners (e.g. battery recycling actors), whereby the data coming in from digital technologies are key. While this networked approach towards circular control is necessary for industrial organisations to slow, narrow or close resource loops, it contrasts the prevalent intra-organisational focus of control system frameworks such as Simons' (1995) levers of control. Rather, it builds on more recent sustainability control research that asserts a combination of top–down and bottom–up information flows (both within and outside organisational boundaries) for improved performance (Johnstone, 2019) by bringing in the horizontal information flows from and between other upstream and downstream actors as important for facilitating circular control in industrial organisations. It also implies the insulated use of strategic alliances (cf. Öberg, 2023) as conditioned by (lack of) resources (e.g. battery recycling) and/or distance (e.g. infrastructure partners for electrification services in remote areas) for large industrial organisations such as the one described.

Additionally, through this networked approach to control, the findings suggest that circular performance improvements, in this case, are primarily for the focal organisation and its customers. It also implies that indirectly, circular performance could be improved for its suppliers. As an example, the data leveraged from the digital technologies mentioned could be used to promote not only more efficient in-house or closed circular innovation strategies (i.e. those related to product or process improvements and better circular service offerings) but also for suppliers to make their own product or process improvements. This is contingent on data sharing to support open innovation strategies for circular PSS ecosystems. While such findings are clear in prior industrial marketing research (e.g. Aarikka-Stenroos *et al.*, 2021; Kühl *et al.*, 2020), the use of digital data for circular planning and performance controls (e.g. related to inventory management, waste reduction, planning for replacements and maintenance) that extend throughout industrial networks has rarely been addressed in control research.

6. Conclusion

As previously suggested, Company X is not (yet) fully circular, but it is making great strides towards increasingly circular PSS whereby the data from various digital technologies is being used in various ways to inform decision-making and behavioural alignment throughout the industrial network as the functions of control. This paper set out to expand on how data from digital technologies were being leveraged by an industrial firm for circular control in the aftermarket. This context was considered especially important for the circular ambitions of any industrial firm in that PSS support particularly the material recovery and recycling aspects to slow, narrow or close resource loops (see Spring and Aruajo, 2017; Yang *et al.*, 2018).

In answering this research question, the findings of this study reveal that the data are being used by non-accountants to inform primarily planning and performance-related controls throughout the industrial network (e.g. inventory management, performance of machines and maintenance, etc.), whereby customers and suppliers are seen as business partners. These controls are often explained through the administrative controls connected to the three main circular service agreements (i.e. electrification, midlife and remanufacturing). Such agreements control resource loops by requiring customers to return components and machines at periodic intervals or end of life to be remanufactured or recycled or through the case organisation retaining ownership of certain resources as assets that are leased to the customer (e.g. batteries and chargers as services).

Nevertheless, the types of digital systems being used to obtain data from the company's products in the aftermarket are many and overlapping; thus, entailing certain challenges related to data capture and system integration. This has resulted in attempts at integrating technical systems in the case company through the rollout of the groupwide ERP system.

This was viewed as helping support circular strategies through bridging local and global digital systems for, in this case, circular control purposes. There is also the added complexity embedded in the geographical reach of the industrial organisation whereby some data from customers cannot be obtained due to infrastructural challenges and remote locations, thus, affecting the potential of descriptive analytics in the aftermarket for prediction and prescription (see Appelbaum *et al.*, 2017).

Overall, the use value of the digital technologies highlighted in the case is clear in that the incoming data are used by non-accountants in the aftermarket make timely decisions, as well as develop products and services that support circularity. While the "potential" of digital technologies for accounting decisions is not something new (see Knudsen, 2020; Quattrone, 2016), one of the main roles of such technologies in the case was the use of accounting information for the service marketing function. Here, the information coming in from the digital data in the aftermarket was also important for strategic marketing decisions (e.g. competitor benchmarking and pre-empting customer needs) and external reporting purposes. Together, such PSS innovations through control in the aftermarket help increase not only firm value but also value for industrial customers and wider circular economies.

6.1 Research contributions, implications and opportunities

The primary contribution of this research regards the creation of an analytical framework that has various implications for sustainability control studies. Firstly, the framework connects digital technologies for circular control in the aftermarket, building on other seminal accounting works in this area such as Jørgensen *et al.* (2023). In doing so, the framework responds to recent calls (e.g. Johnstone, 2024) for more studies on the role of "circular" controls for material recovery phases. Here, the integration of accounting information for the service marketing function in PSS is a key contribution stemming from this model. This moves beyond the prior focus on circular control for product development phases (e.g. Svensson and Funck, 2019).

Secondly, the analytical framework moves beyond the extant sustainability control research focusing on the strategic design of controls for intra-organisational behavioural alignment purposes (e.g. Arjaliés and Mundy, 2013; Corsi and Arru, 2021; Rodrigue *et al.*, 2013). It does this by integrating the two functions of control (i.e. for decision-making and behavioural alignment purposes) and, through the empirical context of the aftermarket in an industrial firm, wherein behavioural alignment for circularity extends to customers and other upstream actors. The findings, therefore, build on prior conceptual studies that emphasise the importance of networked perspectives of control systems for sustainability issues (e.g. Guenther *et al.*, 2016; Johnstone, 2019). Further, the findings from this case extend prior sustainability works that imply the disciplinary effects of control for behavioural alignment in supply chains by focal organisations (e.g. Spence and Rinaldi, 2014) by suggesting that downstream and upstream actors are business partners within circular ecosystems. This, consequently, incorporates open innovation into industrial networks from a control perspective, similar to recent studies (e.g. Biswas and Akroyd, 2022), but links this to circular performance.

Thirdly, the study contributes empirically to the discussion of sustainability integration (Gond *et al.*, 2012) by providing an empirical example of organisational and technical decoupling in an international manufacturing firm. Regarding the organisational dimension of integration, the findings reveal that planning, performance and administrative control decisions were made by non-accountants, a finding that has already been implicated in previous research but is often related to the work of sustainability managers in large organisations (Egan and Tweedie, 2018; Rodrigue and Picard, 2022). Yet, the findings offer examples of the *other* actors conducting accounting and control work for circular PSS, such as those in sales and service positions (i.e. service marketing roles). While this adheres with those other studies that suggest a decoupling between "sustainability" and "accounting" functions (e.g. Frostenson and Johnstone, 2023; Gond *et al.*, 2012; Riccaboni and Leone, 2010), it nevertheless contrasts this by implying a further decoupling between "sustainability" and "circular PSS" functions. Meanwhile, the findings also suggest that technical integration is important for streamlining data sources, quantity and quality for more informed decision-making. This is illustrated in attempts to reconcile the previously "local" (cf. Goretzki *et al.*, 2018) digital "accounting" systems, with a corporate wide standardised ERP system; even though the actual controls implemented, may still be decentralised in response to local factors (ibid.).

Finally, the study contributes by offering empirical examples of the types of digital technologies and controls used to for circularity in the aftermarket of an industrial firm. In doing so, it illustrates how accounting information in the aftermarket supports the marketing function in PSS through superior performance. As stated, the central role of performance and planning controls is clear. But, beyond that, human decision makers remain key for making informed, actionable insights on circularity [i.e. predictive and prescriptive analytics (see Appelbaum *et al.*, 2017)]. This suggests that even though digital systems promote the standardisation of data capture, they require technical and specialist competences in terms of interpreting and making use of the raw data, that is, refining data as accounting information for, in this case, circular decisions. Such competences can be developed through the introduction of social controls (see Johnstone, 2018) and align with the findings of other studies that emphasise the importance of social, cultural, socio-ideological controls for sustainability issues (e.g. Crutzen *et al.*, 2017; Svensson and Funck, 2019), as well as recent studies that suggest the important of digital competence for management control functions (e.g. Fähndrich, 2023).

While this study yields the various analytical, conceptual and empirical contributions listed above, it nevertheless entails some limitations, least due to its single case study design and lack of method theory. Future research should build upon this initial work by incorporating other case studies of manufacturing firms in different contexts to increase the analytical generalisability of the findings. Specifically, more studies are needed that elaborate on the intersection of digital technologies for circular control in the aftermarket. This can be achieved by using the framework presented herein as a tool to frame research on "networked" approaches to control for circular solutions. Additionally, while this paper is grounded in sustainability control system conceptualisations, future studies could adopt other theories or perspectives such as institutional theorising or a dynamic capabilities perspective to further understand and/or explain the decision-making function of control and/or change in different types of inter-organisational networks, with different foci (see also Biswas and Akroyd, 2022). It is also especially of interest to have more empirical research that connects circular control with the service marketing function in the aftermarket of industrial firms, given the importance of PSS for circularity (Johnstone, 2024; Kühl *et al.*, 2020).

6.2 Practical and societal implications

The findings of this study are important for those working in the aftermarket divisions of large industrial organisations that are transitioning towards circularity. This study highlights the importance of accounting information via digital technologies for marketing, product-design improvements and material recovery that can help decrease costs and improve customer satisfaction. Notwithstanding, the findings also suggest that getting the right information depends on streamlined, integrated and well-connected digital systems between upstream and downstream partners. This requires the proper design of a digital infrastructure that is suited to the industrial context. At the same time, aftermarket managers must ensure that their customer facing staff have the required digital competences to be able to convert the incoming data into actionable insights that support the service marketing function for circularity. If these staff are trained in both digital system analytics and circular products or services, they will be better equipped to provide circular solutions for industrial customers. This would lead to environmental performance improvements that extend beyond the industrial network but wider socio-political contexts and circular economies.

Note

1. This term will be used throughout for the sake of simplicity to capture all control studies referring to sustainability issues including circularity.

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Appendix 1

Code	Role	Division or department	Empirical material	Length
S1	Process manager	Aftermarket division	Two separate meetings at local Site 1	150 min
			Online interview	60 min
			Online interview	60 min
S2	Global operations manager	Aftermarket division	Meeting at site	60 min
			Online interview	40 min
S1, S6 and S7	Process manager, group warranty and quality manager and marketing product manager	Aftermarket division	Tour of production facility and group interview at local Site 2	150 min
S3	Global customer success director	Aftermarket division	Online interview	45 min
S4	Global engineering and mobile device manager	Aftermarket division	Online interview	50 min
IT1	IT manager	Information technology department	Online interview	45 min
A1	Global technical service manager	Attachments division	Online interview	45 min
S5	Supply chain sourcing manager	Aftermarket division	Online interview	45 min
S6	Group warranty and quality manager	Aftermarket division	Interview and visit to warranty and quality department at Site 1	60 min
				30 min
S7	Marketing product manager	Aftermarket division	Interview at Site 2	60 min
S8	European president	Aftermarket division	Online interview	45 min
Sust1	Global sustainability booster	Sustainability department	Interview at Site 1	60 min
S9	Global product manager service agreements	Aftermarket division	Online interview	45 min
S10	Vice president of operations	Aftermarket division	Online interview	45 min
Sust2	Zero emission manager	Sustainability department	Interview at Site 1	70 min
	Total			*19.5 h*

Source: Author's own creation

Table A1.
Main primary data sources

Appendix 2

Table A2. Sample interview questions

Sample interview questions	Reasoning	Broader links to analytical model
• What challenges does company X face when it comes to sustainability and how are you overcoming these? • What are some of the novel things that company X is doing when it comes to sustainability in comparison to its competitors? • To gain an understanding of how company X works with "sustainability" issues and the strategic direction it plans to take	To understand the strategic design of controls to guide, monitor and motivate	Strategic design of controls to guide, monitor and motivate
• What digital systems/software do you use in your daily work? • What is the role of digitalisation in supporting sustainability? How have digital tools improved your own sustainability work? Any problems? • How are digitalisation, automation and electrification ambitions connected in the aftermarket?	To gain an understanding of the types of digital technologies used in the interviewee's daily work and any connections to sustainability	Types of digital technologies used to develop, analyse and respond to information for circular decision-making
• How do you communicate the value of smart services to your customers? • How do you get information/feedback from customers and what role do digital technologies play in this? • How do you make use of feedback from both customer and data systems? • What happens with this data?	To gain an understanding of the types of digital technologies used to obtain customer information for decision-making, monitoring, motivating and guiding purposes	The use of digital technologies for control functions (i.e. decision-making and behavioural alignment)
• How well is company X doing in driving the sustainability transformation/innovations of the industry? • How well is company X doing in ensuring the reduced environmental impact of products and processes? How does this compare to competitors and what can it do better?	To gain an understanding of the circular transitions of case company	Circular performance outcomes
• How important have digital technologies been for company X on this sustainability/circular journey and what challenges have they brought up? For example, what new skills are needed for company X and how have internal systems or controls changed? • What role do upstream and downstream actors have in this?	To gain an understanding of the benefits and challenges of obtaining data that can be used as information from digital technologies in the aftermarket for circular PSS	Connections between accounting information (via digital technologies) and both intra- and inter-organisational circular control decisions

Source: Author's own creation