Journal of Marketing Management

ISSN: 0267-257X (Print) 1472-1376 (Online) Journal homepage: https://www.tandfonline.com/loi/rjmm20

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To cite this article: Alexey Sklyar, Christian Kowalkowski, David Sörhammar & Bård Tronvoll (2019) Resource integration through digitalisation: a service ecosystem perspective, Journal of Marketing Management, 35:11-12, 974-991, DOI: 10.1080/0267257X.2019.1600572

To link to this article: https://doi.org/10.1080/0267257X.2019.1600572

JOURNAL OF MARKETING MANAGEMENT
2019, VOL. 35, NOS. 11–12, 974–991
https://doi.org/10.1080/0267257X.2019.1600572

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Resource integration through digitalisation: a service ecosystem perspective

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ABSTRACT
As digitalisation increasingly encompasses entire service ecosystems, it modifies resource integration patterns that connect ecosystem actors through strong and weak ties. To clarify how technological development contributes to this change, and how resource integration transforms the service ecosystem, this qualitative case study explores the digitalisation strategy of a market-leading systems integrator in the maritime industry. Based on 40 depth interviews with managers, the findings show how technology increasingly serves as a key operant resource in the transformation of resource integration patterns. The study contributes to ecosystem dynamics research by identifying major differences between the pre-digitalised and digitalised states of a service ecosystem, and demonstrates the dual role of technology in both increasing pattern complexity and facilitating coordination of that complexity.

ARTICLE HISTORY
Received 14 February 2018
Accepted 8 March 2019

KEYWORDS
Digitalisation; service ecosystems; resource integration; servitization; strong and weak ties; operant resources

Introduction

From back-office efficiency to reconfigured production, distribution and service operations, digitalisation enables incumbent firms to find new ways of providing solution offerings to their customers (Sklyar, Kowalkowski, Tronvoll, & Sörhammar, 2019). Given that no business is an island (Håkansson & Snehota, 1989), this transformation extends beyond the individual firm (Ulaga & Reinartz, 2011) to encompass resource integration between actors embedded in larger structures as elements of an ecosystem (Granovetter, 1985; Vargo & Lusch, 2016). Resource integration is the means by which actors co-create context-specific, uniquely determined value, both for themselves and for other actors in the ecosystem (Kleinaltenkamp et al., 2012). In recent years, digital technology has become a critical facilitator of value co-creation (e.g. Balaji & Roy, 2017). In this process of changing resource integration patterns, the distinct configuration of actors, resources and activities enabled by new technology transforms service ecosystems (e.g. Håkansson, 1989; Storbacka, Brodie, Böhmann, Maglio, & Nenonen, 2016). At the same time, technologies have become smarter, incorporating more human-like capabilities and increasingly acting without human intervention (Maglio & Lim, 2018).

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As a result, the role of technology – and especially of digital or information technology – has shifted from operand to operant resource (Akaka & Vargo, 2014; Lusch & Nambisan, 2015). This novel role remains underexplored and warrants further investigation (Kleinaltenkamp et al., 2012).

The rapid and disruptive nature of technological change makes it vital that incumbent firms are able to reconfigure their resource integration patterns, both in their own strategic interests and for the viability of the ecosystem as a whole (cf. Storbacka et al., 2016). However, in pursuing digital service transformation, incumbent firms are likely to encounter a paradox, as the resources that brought success in its traditional domain may become 'core rigidities' that constrain transformation (Leonard-Barton, 1992). These core rigidities emerge within a pre-existing network of strong and weak ties (Granovetter, 1973), where strongly tied patterns of resource integration make it difficult to adapt to technology-driven environmental changes (Lieberman & Montgomery, 1988). As little is known about the links between overcoming core rigidities and changes in service ecosystems, there is a need for empirical research on the significance of strong and weak ties in the context of digitalisation. By examining the interplay between the technology and ecosystem change, the aim of the present study is to clarify how resource integration among actors connected by strong and weak ties transforms the service ecosystem.

Based on in-depth interviews and secondary sources, this extensive study of a market-leading systems integrator pursuing a digitalisation strategy reveals how digital transformation within the ecosystem increases the importance of software and digital services in the interactions between actors. As technology mediates those interactions, building a digital infrastructure becomes fundamental to the viability of the service ecosystem, extending software to third-party offerings without being confined to the hardware of a single supplier.

The findings further suggest that digitalisation of the service ecosystem increases the number and importance of weak ties, corresponding to the growing scalability of digital services across customer segments, creation of real-time information links, and integration of software interfaces between previously unconnected actors. Our findings also demonstrate that technology's increasing role as an operant resource is closely linked to changes in resource integration patterns. As software and digital services become critical to resource integration, that integration becomes increasingly effective by virtue of technological support for continuous interaction and the accompanying need for greater coordination.

As the first known empirical study to explicitly link discussion of operand and operant resources to resource integration patterns, the present paper enhances our understanding of service ecosystem dynamics and change. In addition, it augments research at the intersection of the literature on service-dominant logic and strong and weak ties. Despite growing research interest in this area, only a few studies to date (Laud, Karpen, Mulye, & Rahman, 2015; Lusch & Vargo, 2014; Lusch, Vargo, & Tanniru, 2010; Siltaloppi & Vargo, 2017) have linked these two discourses. The study reveals major differences between the pre-digitalised and digitalised states of a service ecosystem and demonstrates the dual role of technology in (1) increasing the complexity of resource integration patterns and (2) enabling actors to successfully coordinate and manage that complexity.

Theoretical framework

Resource integration in service ecosystems

Service-dominant (S-D) logic offers a multi-actor, systems view of value co-creation, emphasising the integration of resources for the benefit of economic and social actors (Lusch & Vargo, 2014). Like all actors, incumbent firms integrate resources as part of their value creation process. This ability and permission to use or integrate a resource is what ultimately facilitates exchanges between actors (e.g. Kleinaltenkamp et al., 2012). We argue here that continuous resource integration creates strongly tied resource-integrating patterns that become institutionalised in a specific use context. This process of interaction between actors creates core rigidities in a service ecosystem, enabling resource integration that simultaneously constrains change (e.g. by inhibiting adoption of new technologies).

Service ecosystems serve increasingly as the context and unit of analysis for value co-creation and resource integration (Vargo & Lusch, 2016). A service ecosystem can be defined as a 'relatively self-contained, self-adjusting system of resource-integrating actors connected by shared institutional arrangements and mutual value creation through service exchange' (Lusch & Vargo, 2014, p. 161). This service ecosystem perspective pursues a systemic, dynamic and contextual understanding (Chandler, Danatzis, Wernicke, Akaka, & Reynolds, 2019; Tronvoll, 2017). This is critical for understanding the complexity of digitalisation in service ecosystems, as the structure drives behaviour within the system, and any shift in the underlying rules of the system can serve as a powerful point of leverage for change (Meadows, 2008). While a better understanding of an ecosystem's underlying institutional rules can provide a more holistic understanding of resource integration patterns, it is important to account for institutions as a mechanism of coordination and cooperation for mutual value creation.

Ecosystem change and the strength of weak ties

Resource integration does not happen by accident; rather, institutions coordinate how resources are integrated (Edvardsson, Kleinaltenkamp, Tronvoll, McHugh, & Windahl, 2014). An institution is 'any structure or mechanism of social order and cooperation governing the behaviour of a set of individuals within a given human community' (Miller, 2014, p. 514). To that extent, institutions can be said to specify 'the rules of the game' (North, 1990, p. 4), including 'regulative, normative and cultural-cognitive elements that, together with associated activities and resources, provide stability and meaning to social life' (Scott, 2008, p. 48). The role of institutions, then, is to provide guidelines and resources for action, and to prohibit or constrain certain activities and interactions among engaged actors. In this way, institutions influence resource integration patterns, both through formal constraints, such as rules and laws, and by means of informal constraints, such as norms and conventions. It follows that individual institutions rarely act in isolation but operate as nested and interrelated sets of institutions or institutional arrangements that govern actors (Lawrence & Suddaby, 2006), constraining and enabling resource integration. To that extent, institutions can serve as powerful drivers of change and can shape the nature of change across service ecosystem levels and contexts (Dacin, Goodstein, & Scott, 2002). An ecosystem's institutional arrangements commonly include a combination of deeply embedded strong ties and loosely affiliated weak ties (Uzzi, 1996).

An ecosystem perspective posits that the formation of a business network or an organisation (internal network) occurs within a pre-existing network of strong and weak ties (Granovetter, 1973). On each occasion that actors integrate resources, they are likely to learn something that makes the next iteration slightly different in adapting to a changed context, making the ecosystem self-adjusting. Such changes can be understood as structural adjustments (Evans, 1989) or as alterations to the system overtime. Ecosystem actors become strongly tied overtime as they learn to utilise each other's heterogeneous resources in a more precise and productive way (Alchian & Demsetz, 1972), creating core rigidities by adapting their internal processes and routines to better match each other's resources. The more adapted their internal processes and routines become, the stronger the ties between actors (Granovetter, 1973). Ties can be broadly characterised in terms of three concentric circles of social relationships: (i) strong ties, (ii) weak ties and (iii) no ties (that is, no relationships among actors, as if they were strangers) (Aldrich, Elam, & Reese, 1996; Granovetter, 1973). This implies that all resource integration within a service ecosystem occurs between strongly and weakly tied actors. It also implies that a single actor is dependent on resources controlled by other actors – both for its own strategic benefit and for the viability of the ecosystem as a whole (e.g. Johanson & Mattsson, 1994).

Strongly tied ecosystem actors integrate more resources with each other than with weakly tied actors. These repeated activities also foster trust between the actors, facilitating collective action (Burt, 2003; Ostrom, 1990) in the form of effective and efficient resource integration. The more frequently resources are integrated, the more mutually knowledgeable actors become. As no new resources flow between strongly tied actors, these strong links create core rigidities and redundancy in the ecosystem, which inevitably constrains structural opportunities (e.g. Granovetter, 1973). These core rigidities (Leonard-Barton, 1992) often take the form of practices regarding what resources to integrate and how best to integrate them. The rigidities formed by these institutionalised rules make it difficult for the incumbent firm to adapt, and this 'incumbent inertia' may even create resistance to environmental change (Lieberman & Montgomery, 1988). As the only way for an actor in an ecosystem to acquire novel resources beyond those already available is to interact with weakly tied actors, weak ties play a crucial role in ecosystem transformation and adaptation to new conditions (cf. Granovetter, 1983), such as digitalisation. As such, the 'strength of weak ties' depends on the structural reconfiguration of strong and weak ties (Granovetter, 1973; Newman & Dale, 2005).

Technology as operand and operant resource

Technology has been described as both *operand* resource (facilitator or enabler) and *operant* resource (initiator or actor) in value creation (Lusch & Nambisan, 2015). Digital and technological advances mean that machines, technologies and other resources previously considered operand are now increasingly capable of adjusting to their environment as operant resources (Akaka & Vargo, 2014). By viewing technology as an operant resource, actors can extend their ability to reconfigure resource integration patterns within the ecosystem, as for example in information technology's capacity to enable and facilitate knowledge sharing and coordination (Nambisan, 2013).

Unlike strongly tied ecosystem actors, weakly tied actors are more likely to perceive new properties as a resource – for instance, seeing the potential to separate and transport information independently of people and materials (Normann, 2001). Weakly tied actors can also visualise how that same resource can be recombined (or unbundled and rebundled; Normann, 2001) into new resource integration patterns. In contrast, a service ecosystem involving strongly linked actors may not perceive these possibilities; in one well-known example, technology company Kodak and other strongly linked actors perfected the process of developing film, but weakly linked actors like Apple visualised how to utilise disruptive digital technologies in this context. While weakly linked actors can see operant properties of such new technologies – that is, as resources that produce effects – strongly linked incumbent firms tend to perceive these technologies as an operand resource, on which an act is performed (e.g. Lusch & Nambisan, 2015). In this sense, technologies and their resource value are socially constructed (Orlikowski, 1992; Pinch & Bijker, 1984; Wieland, Hartmann, & Vargo, 2017) by institutional rules within the ecosystem.

The core rigidities of strongly tied actors create institutionalised rules that determine the meaning of certain resources, which resources to integrate, and how to best integrate those resources. When the service ecosystem is undisturbed by disruptive technology, it conforms to Alderson's (1965) idea of a perfectly heterogeneous market, in which actors possess and exchange unique resources, and a resource's value depends on how it is integrated with other resources and on how that integration is perceived by the beneficiary (Lusch & Vargo, 2014). In cases of technology-driven environmental change, however, the ecosystem's institutionalised rules may inhibit change or even blind the actors to the potential use value of the new or altered resource. The concept of change is of direct concern to incumbent firms seeking to adjust resource integration patterns in the service ecosystem. From an S-D logic perspective, change is ongoing, as each resource integration activity creates potential change in respect of all operand and operant resources (Kowalkowski, Persson Ridell, Röndell, & Sörhammar, 2012). This highlights how ecosystem actors can change and adapt their resource integration patterns, and how technology, seen increasingly as an operant resource, contributes to this transformation.

Research method

Approach and sampling

To address the research objective, a qualitative case study was conducted. While the topic of resource integration has received increased attention of late, especially within S-D logic, the role of technology in this regard remains unclear. It was, therefore, deemed appropriate to employ an in-depth case study to better understand and explain the complex social phenomenon of digital transformation (Bryman & Bell, 2015). The abductive research process (Dubois & Gadde, 2002) entailed iterative movement between the literature and empirical observation.

Using a purposeful sampling approach (Miles & Huberman, 1994), we negotiated access to a market-leading systems integrator that has actively pursued a digitalisation strategy. The company (Navicula[1]) is part of an established multinational industry group and is a market leader worldwide. As a systems integrator, Navicula is part of a business ecosystem providing maritime solutions, including a wide range of equipment and onshore and offshore services. Customers are typically vessel owners and operators responsible for large international fleets. Because of the sensitive nature of the study, the company and participating individuals were anonymised to preserve confidentiality.

The case was selected on the basis of three inclusion criteria. First, the company should have made a strategic shift to embrace digitalisation and service-led growth. In this regard, managers and executives in the multinational's central functions – which are independent of one another – identified Navicula as the group's leading firm in terms of digital transformation, prompting us to approach the company's key decision makers. The company had successfully pursued what Sklyar et al. (2019) refer to as 'digital servitization'; that is, the utilisation of digital tools for the transformational processes whereby a company shifts from a product-centric to a service-centric business model. A second criterion was ongoing strategic investment in digitalisation, which would enable us to analyse the changing role of technology in resource integration while avoiding the kind of speculative future-oriented discussion that is typical of such studies. Third, we required high-level access to key informants and secondary data sources (including confidential internal documents). By focusing data collection on the principal actor in the ecosystem, this actor-network delimitation ensures more reliable comparison and theory development (Halinen & Törnroos, 2005).

Data collection and analysis

From May 2016 to December 2017, 40 in-depth interviews were conducted with 33 key informants at Navicula and within the wider multinational industry group. The interviews varied in duration from 30 min to 3.5 h, depending on the importance of the interview and the informant's accessibility. Informants were identified by means of snowball sampling (Coleman, 1958), mainly involving discussions with the vice president in charge of the digitalisation initiative. All but three of the interviews were conducted face-to-face at one of the company sites across Europe. Video/phone interviews were conducted where the respondent worked in another part of the world and/or follow-up meetings did not require a face-to-face meeting. In most cases, one to three researchers and one company representative participated in the interview; occasionally, there were several informants. As recommended by Miles and Huberman (1994), when new questions emerged, key informants were re-engaged in order to acquire more detailed accounts. Overall, informants exhibited great openness and genuine interest in the study. Table 1 provides further details of the interviews.

The semi-structured interviews sought to unravel the changes occurring in the service ecosystem as it moved from a pre-digitalised to a digitalised state. In particular, we were interested in developing an in-depth understanding of resource integration mechanisms and the ties between actors in the ecosystem. For that reason, we tailored our questions to each informant in light of their position, knowledge and experience. Primary data also included observations made during meetings (e.g. sales pitches to potential clients) and visits to the two state-of-the-art service centres launched by the company to support digital transformation. Secondary data were acquired from internal company documents (e.g. strategy documents, press releases), as well as from websites, newspapers and social media.

Table 1. Conducted interviews.

Informant's position	Interview duration (hours and minutes)			
Analyst (Customer Service), two informants	01:12	02:08		
Business Development, Global Service	00:30	01:00		
Executive Business Unit Manager	00:54			
Global Product & Portfolio Manager (Digital Solutions)	01:28			
Global Sales & Business Development	01:42			
Global Technical Support Manager	01:30	01:00		
Global Technical Support Manager	01:49			
Information Manager & Global Product Manager	02:33			
Integrated Operations Program Manager	01:28			
New Energy Efficiency Manager	01:35			
Product Manager	00:53			
Project Manager	00:23			
Project Manager	01:47			
Sales engineer (IT)	00:30			
Senior Vice President (Collaborative Operations)	01:08	01:27	03:30	00:30
Senior Vice President (Customer Segment)	01:54			
Senior Vice President (Global Operations)	01:39			
Senior Vice President (Information & Control)	01:24			
Service Manager	01:01	00:13		
Service Manager (Local Region)	01:26			
Service Sales Manager Merchant	00:30			
Technical Advisor	01:20			
Technology Manager	00:23			
Vice President (Customer Segment)	01:30	01:00		
Vice President (Digital Services)	01:08	01:00	03:20	
Vice President (Head of Global Services)	01:08	01:38		
Vice President (Region)	01:41			
Vice President (Service)	01:41			
Embedded Systems Coordinator (Multinational Industry Group)	01:26			
Project Manager, Corporate Research (Multinational Industry Group)	01:30			
Senior Scientist, Industrial Software System (Multinational Industry Group)	01:30			
User Experience & Industrial Design (Multinational Industry Group)	01:30			

In total, the interview transcripts yielded about 700 pages of single-spaced text. Once saturation was achieved, transcripts, notes and secondary data were read and coded to identify key issues and themes, using NVivo software (Hoover & Koerber, 2011). Coding was based on comparative content analysis supported by peer evaluation (Miles & Huberman, 1994). All the researchers who collected the data also participated in coding for independent parallel analysis and triangulation (Bryman & Bell, 2015). The process of analysis involved reading the interview transcripts and field notes and then comparing and interpreting each record, facilitating re-extraction and re-coding of the data based on discussions between the researchers. After categorising the data on the basis of the theoretical framework (Yin, 2009), the findings were compared to the current literature, and a report was written, with a descriptive summary for each category (Saunders, Lewis, & Thornhill, 2012).

Findings

Pre-digitalised service ecosystem

Prior to the early 2010s, Navicula's ecosystem was in what we characterise as a pre-digitalised state. In the absence of a digital infrastructure that would allow continuous real-time connection, actors interacted by means of analogue or non-continuous digital communication (e.g. email). At the operational level, this affected interaction between both onshore and offshore units (individual vessels) of Navicula and its customers. For the latter group, the absence of real-time information links to onshore units amounted to the relative isolation of vessels, which typically had to act largely independently when operational.

In addition to this information disconnect between onshore and offshore units, individual vessels were subject to intra-unit information disconnect. As the captain and bridge crew overseeing the vessel and navigation and the chief engineer and engine room crew responsible for vital technical systems are traditionally located in different parts of the vessel, the absence of any real-time digital infrastructure limited their information exchange. This meant that the chief engineer and engine room crew were entirely responsible for maintaining equipment in working condition but generally had minimal input to navigational aspects of operation.

The effect of this relative isolation of individual vessels and intra-unit information disconnect was that while customers' onshore units typically had a remote connection to the captain and bridge crew, Navicula's onshore unit was remotely connected to the chief engineer and engine room crew, as the firm's offerings at that time focused exclusively on those actors. Overall, neither group had continuous remote access to entire vessels, effectively turning the vessels into 'black boxes' for onshore units in terms of real-time information. Figure 1 provides an overview of the pre-digitalised service ecosystem, showing the critical interactions between key actors as described (i.e. the focal firm was in reality interacting with multiple customers that operated numerous vessels).

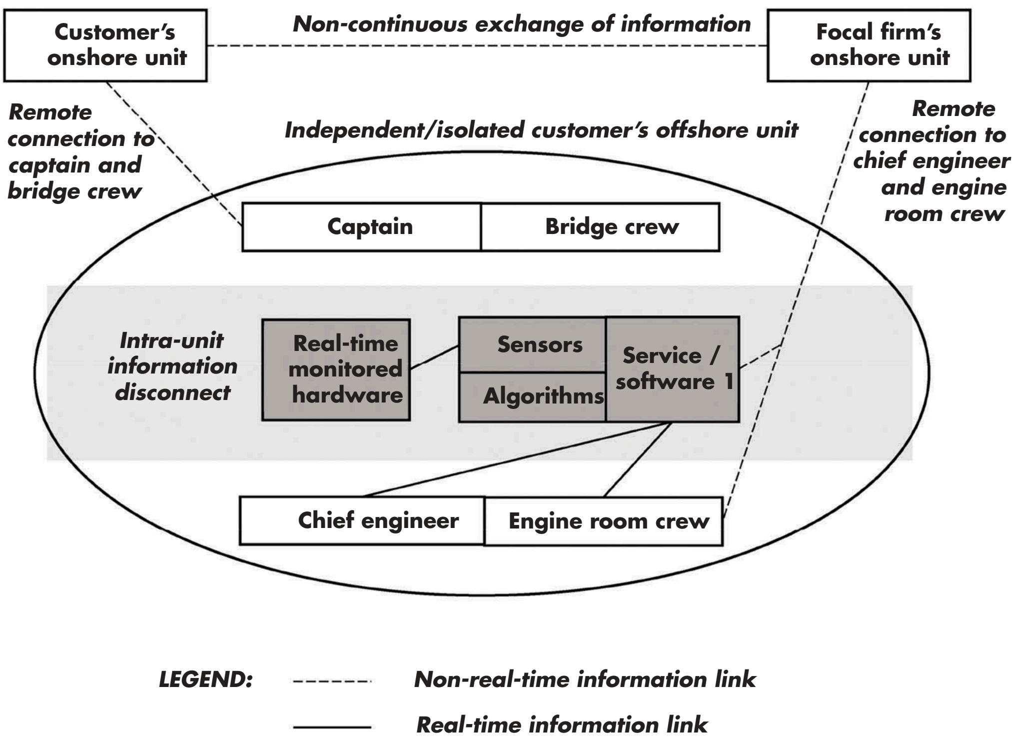

Figure 1. Pre-digitalised service ecosystem.

In the service ecosystem described above, technology played a secondary, supporting role and the existing infrastructure limited the extent and scope of digital offerings. Services in the pre-digitalised ecosystem were developed with a focus on hardware, resulting in limited scalability across customer segments and restricted extendability to third-party suppliers. As an example of such a hardware-centric service, Navicula introduced a digital offering for remote monitoring of the hardware developed within Navicula's multinational industry group. The underlying software had originally been offered as a service by a firm from the same group that was not operating in the maritime industry. The firm's strong connections to Navicula – including an ongoing R&D collaboration – prompted Navicula to adapt the offering to the maritime context. After significantly improving the software, Navicula offered the service to the customer segment that was explicitly requesting this functionality. Despite success in one customer segment, extending this digital offering to other segments or to third-party hardware suppliers was not feasible at the time because of the service ecosystem's pre-digitalised state. This represented a major obstacle, which was eliminated only after the ecosystem was digitalised.

Digitalised service ecosystem

From the early 2010s, Navicula's ecosystem transitioned into what we describe as a digitalised state. With Navicula driving the change, rapid technological developments enabled the ecosystem actors to build a digital infrastructure for continuous real-time connectivity, and as a result, digital technology now mediated all actors' interactions. As part of this new infrastructure, Navicula and its customers created onshore operations centres to integrate digital activities at a single physical location. In turn, interactions between Navicula and its customers now employed Navicula's customer portal and its numerous interfaces, each customised for a specific user. The portal allowed immediate access to data accumulated at ever-increasing speed and reaching unparalleled volumes; storage was enabled by the previously non-existing third-party cloud services.

Digitalisation of the service ecosystem also affected interactions between onshore and offshore units. Real-time remote connectivity eliminated the relative isolation of vessels, allowing continuous monitoring by the onshore operations centres of Navicula and its customers. These operation centres could also access the entire vessel rather than only some on-board actors as was the case in the pre-digitalised ecosystem. Finally, instead of interacting only with human actors and collecting information from them, the onshore units were now able to receive data directly from the source (e.g. sensors), storing this information remotely in the cloud for easy access by any actor – onshore or offshore – through Navicula's customer portal.

The customer portal also resolved the intra-unit information disconnect that undermined the pre-digitalised ecosystem, allowing simultaneous remote access for both the captain and bridge crew and the chief engineer and engine room crew. For these two groups of actors, their decision-making processes were significantly enhanced by this technology-enabled continuous intra-unit exchange of information. Overall, the previous situation in which vessels were seen as 'black boxes' in terms of real-time information was radically changed, with offshore operations fully transparent both to onshore units and internally. Figure 2 provides an overview of the digitalised service ecosystem, depicting critical interactions between key actors.

In the digitalised ecosystem described above, technology moved from a secondary and supporting role to being critical to interaction, and customers now viewed digital offerings as a key selection criterion when choosing suppliers. This increasing customer demand for digital services and the rapid development of relevant technologies radically transformed how ecosystem actors interacted. For example, in driving the ecosystem's digitalisation, Navicula integrated all digital services and associated software in a single platform on the customer portal, providing all actors with continuous access to salient information.

The ecosystem also began the transition from hardware- to software-centric services. For example, Navicula developed digital offerings built around software that was compatible with third-party hardware, providing navigational advice to the captain and bridge crew, along with energy-efficiency advice to those same actors and to the chief engineer and engine room crew. Various interfaces including third-party sensors extended the functionality of these digital services to an unrivalled extent, making Navicula the only player in the market to integrate a full spectrum of information for its customers. Finally, the new digital infrastructure allowed the firm to scale and extend these novel services across customer segments in a way that would have been impossible in the pre-digitalised ecosystem.

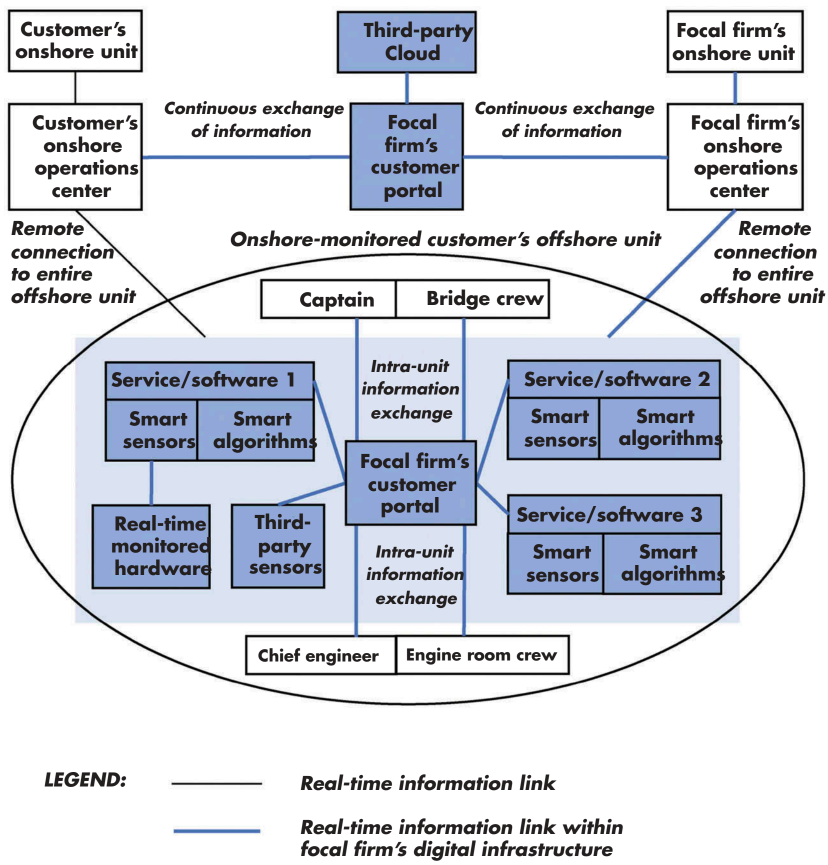

Figure 2. Digitalised service ecosystem.

Discussion

Our findings reveal three major differences between the pre-digitalised and digitalised states of the service ecosystem in terms of the interplay between technology, strong and weak ties and resource integration patterns. In the pre-digitalised ecosystem, interactions between actors typically relied on non-continuous (e.g. analogue) communication; as a result, strong ties predominated in resource integration patterns. For example, the operational decision-making of key on-board actors was based mainly on interactions with other actors located in close proximity and linked by strong ties (i.e. those unaffected by the intra-unit information disconnect). In contrast, the digitalised ecosystem technology enabled weak ties to play a significant role in mediating interactions; for example, the real-time on-board operations of entire vessels now became accessible for previously disconnected actors. As a result, novel resource integration patterns were formed as the technology facilitated weakly tied interactions, reflecting the posited profound effect of digitalisation on resource integration patterns (Storbacka et al., 2016). In this way, technology became critical for resource integration, reflecting its transition from operand to operant resource.

The prevalence of resource integration patterns based on strong ties in the pre-digitalised ecosystem is further exemplified by the low scalability of digital services. For example, although the focal firm created a digital offering for one of its customer segments, strong ties prevented scaling up of the service for other segments. Core rigidities meant that most customers were unprepared to integrate novel resources because of the scarcity of weak ties. In contrast, the digitalised ecosystem made it possible to scale up this and other services across segments where weak ties now linked previously unconnected actors. The digital infrastructure played a critical role in improving the scalability of digital services by enabling continuous information links between actors, so increasing the number of weak ties within the ecosystem. This aligns with the extant literature suggesting that digital infrastructure can help to bring diverse actors together, enabling collaboration in the ecosystem (Lusch & Nambisan, 2015).

The two states of the ecosystem also influenced the effectiveness of resource integration. In the pre-digitalised ecosystem, actors were often forced to interact in ways that were close to analogue, relying on strong ties that would create core rigidities, resulting in relatively ineffective resource integration patterns. In the digitalised ecosystem, on the other hand, onshore units' continuous access to vessels and on-board intra-unit information exchange enabled resource integration that involved many more actors in co-creation. In this way, real-time digital connectivity ultimately increased the overall effectiveness of resource integration patterns. These findings align with the posited importance of weak ties for improving resource exchange in service ecosystems (Laud et al., 2015) and provide empirical support for the role of digitalisation in enhancing the various patterns' effectiveness (Storbacka et al., 2016). The findings also confirm the changed role of technology from operand to operant resource, where the latter is considered fundamental to service ecosystems (Akaka & Vargo, 2014).

Together with associated changes in ties between actors and in resource integration patterns, the major difference between the two states of the ecosystem in relation to software and hardware further confirms the changed role of technology. In the pre-digitalised ecosystem, there was a close link between the suppliers' internal development of software and hardware, resulting in hardware-centric digital services. In the digitalised ecosystem, however, the focal firm concentrated on novel types of resource integration, creating multiple interfaces with third-party offerings from weakly tied suppliers. As a result, the number and scope of those interfaces distinguished the firm's ecosystem fundamentally from its competitors. The latter remained focused on the traditional strong ties that would ultimately lead to the formation of core rigidities, making it impossible (at the time) to provide their customers with such novel offerings. In contrast, resource integration patterns in the focal ecosystem originated from weakly tied, technology-enabled interactions, resulting in more value creation for all actors. These findings confirm the posited role of weak ties 'in offering a relative advantage in competing resource-driven service systems' (Laud et al., 2015, p. 519).

The growing complexity of the resource integration patterns due to the increased number of actors in the digitalised ecosystem also required greater coordination of resource integration activities. For example, the creation of a customer portal by the focal firm allowed resources to be integrated between multiple actors in a way that would not have been possible in the pre-digitalised ecosystem. Despite the radical increase in pattern complexity, technology enabled this coordination, confirming the posited importance of improving access to resource-integrating actors and their resources (e.g. Madhavaram & Hunt, 2008; Wieland et al., 2017). This finding also extends discussion of the 'choreography' of resource integration patterns (Storbacka et al., 2016) by demonstrating the dual role of technology in increasing pattern complexity and enabling service ecosystem actors to successfully address this issue. Table 2 summarises the discussion around focal service ecosystem transformation from pre-digitalised to digitalised, based on changes in technology, strong and weak ties and resource integration patterns.

Implications for theory and practice

Theoretical implications

As the first known empirical study to explicitly link discussion of operand/operant resources (Lusch & Vargo, 2014; Madhavaram & Hunt, 2008) and resource integration patterns (Storbacka et al., 2016), the present work enhances our understanding of service ecosystem dynamics and change. In particular, the case study design illuminates how technology's changing role as an operant resource is linked to the posited impact of digitalisation on resource integration patterns, providing empirical support for the latter. The study exposes a clear distinction between the pre-digitalised and digitalised states of a service ecosystem, involving the radical transformation of interactions between actors. While actors in the pre-digitalised ecosystem interacted in relatively ineffective and close to analogue ways, real-time digital connectivity improved the overall effectiveness of resource integration patterns. By facilitating coordination between actors, technology as an operant resource proved critical in enhancing ecosystem interactions. In this regard, technology played a dual role, increasing the complexity of resource integration patterns while enabling ecosystem actors to better manage this complexity.

In addition, the study contributes to research at the intersection of service-dominant logic and strong and weak ties. Despite growing interest in this area, only a few studies (Laud et al., 2015; Lusch & Vargo, 2014; Lusch et al., 2010; Siltaloppi & Vargo, 2017) have linked these two discourses. The findings suggest that the modified role of technology is

Table 2. Service ecosystem transformation from pre-digitalised to digitalised.

Service ecosystem	Technology	Strong and weak ties	Resource integration patterns
Pre-digitalised	The available software and digital services play a secondary, supporting role in the ecosystem, reflecting technology's role as operand resource.	Digital services are mainly scalable within (but not across) customer segments because of core rigidities, with weak ties playing a minor role.	Interactions between actors are not continuously mediated by digital technology; software and digital services are less prominent in resource integration patterns.
	Digital infrastructure is non-existent and mostly analogue in its efficiency.	Strong ties between actors predominate because of a scarcity of continuous real-time information links.	Resource integration patterns are ineffective because of isolation among the main actors (e.g. between onshore and offshore units).
	Software is closely linked to hardware, usually within (but not across) suppliers.	The role of weak ties is minimal because software and hardware integration occurs mainly within suppliers.	Low complexity of resource integration patterns means no significant effort is made to coordinate actors' resource integration activities.
Digitalised	Software and digital services play a fundamental role in the ecosystem, reflecting technology's role as operant resource.	Scalability of digital services extends across customer segments, with weak ties growing in importance.	Interactions between actors are increasingly mediated by digital technology, with software and digital services becoming critical to resource integration patterns.
	The created digital infrastructure becomes indispensable for the service ecosystem's viability.	The number of weak ties increases because of continuous real-time information links between actors.	Resource integration patterns become considerably more effective as a result of the elimination of isolation between actors.
	Software becomes increasingly independent of any single supplier's hardware and is extended to third-party offerings.	Weak ties grow in importance as a result of widespread integration of software interfaces across suppliers.	As the complexity of resource integration patterns increases considerably, more effort is required if actors are to coordinate their resource integration activities.

directly associated with the increasing importance of weak ties between actors within the service ecosystem. It is commonly thought that the marginal cost of producing and upscaling service operations should ideally be close to zero once digital services are in place (Rifkin, 2014). Interestingly, the present findings show that digital services alone were insufficient for effective resource integration through scalability, given the predominantly strong ties and low degrees of digital maturity among ecosystem actors. Instead, implementation of a digital infrastructure was required in order to transform resource integration patterns by increasing the number of weak ties. In this way, the study further extends discussion of the effects of digitalisation on resource integration patterns (Storbacka et al., 2016) by incorporating the discourse on strong and weak ties.

Managerial implications

At a practical level, the present study has important implications for firms operating in environments where digitalisation is imminent or ongoing. First, we suggest that managers can rely on the changed status of technology to actively influence their service ecosystem. As these findings confirm, the increasingly critical role of technology in both intra- and inter-organisational interaction drives ecosystem transformation through the creation of an ecosystem-wide digital infrastructure. The latter enables incumbent firms to establish continuous information links between previously disconnected individuals, divisions and organisations and provides a means of overcoming established core rigidities. In particular, where core rigidities obstruct adaptation to environmental changes, resolving the information disconnect enhances decision-making processes and transparency of operations across the service ecosystem. As a result of this transformation, the increased effectiveness of interactions enables incumbent firms to adapt to rapid technological changes in their environment and to successfully leverage such changes for critical competitive advantage – both for individual firms and for the ecosystem as a whole.

Second, an ecosystem-wide digital infrastructure is likely to be of help to firms facing scalability challenges in relation to digital services. Without this infrastructure, digital services are often confined to individual customers or customer segments, and are, therefore, scalable only to a limited extent (if at all). In contrast, by enabling continuous information links between players, digital infrastructure improves collaboration in the ecosystem, so improving scalability across customer segments. Moreover, as customer willingness to adopt novel offerings depends largely on the potential benefits, the infrastructure underpinning digital services offers a strong incentive to use them and provides access to previously unreachable players in the ecosystem.

Third, given the increasingly complex interactions among a growing number of ecosystem actors, our findings suggest the importance of coordinating crucial activities within the ecosystem. To this end, a firm driving the transformation can create a platform that unifies all players and provides them with continuous access to business-critical data and information (as in the customer portal described here). On a closely related point, managers should also consider extending the software that underpins digital services beyond their own firm's hardware. Multiple interfaces with third-party offerings render digital services independent of any single hardware supplier, with additional benefits for the entire ecosystem. For example, suppliers can secure sustained competitive advantage by broadening the functionality of their offerings to otherwise unattainable levels. In turn, both customers and partners can benefit from more value created by such software-based synergies, ultimately enhancing the competitiveness of the ecosystem as a whole.

Limitations and further research

This study has several limitations that suggest fruitful avenues for further research. First, while we sought to provide an inclusive account of resource integration through digitalisation within the focal service ecosystem, future studies might usefully corroborate our findings by investigating other contexts and types of ecosystem. This seems especially interesting in light of the likely differences between industries when pursuing digitalisation. For instance, while in the present case the new digital infrastructure became indispensable for ecosystem viability in eliminating between-actor isolation, industries that do not share the same high degree of isolation might experience a different outcome. Additionally, while the maritime context explored here exemplifies a relatively advanced digitalised service ecosystem, other industries may not yet have reached this stage, and cross-industry comparison may therefore be useful. In particular, it would be interesting to compare differing approaches that reflect the varying digital maturity of actors in pre-digitalised ecosystems.

Second, although qualitative data and a single-case study research design were well-suited for present purposes, alternative methodologies are likely to provide additional insights. For example, it seems worthwhile to examine the impact of digitalisation on performance, with specific reference to technology as an operant resource at both firm and ecosystem levels. Similarly, in terms of both theory and practical utility, generalisability may be enhanced by quantifying the respective role and impact of weak and strong ties. On a related note, the interplay between technology, strength of ties, and resource integration patterns should be studied in greater depth. For instance, future research might examine how variations in the magnitude of each of these three factors across ecosystems (and possibly different sequences of deployment) ultimately affect the scope and complexity of their interplay.

Finally, while we focused here on 'analytical intelligence' (Huang & Rust, 2018) – that is, technology that can process information to solve a problem, learn from it, and adapt systematically – more advanced forms of technology support intuitive and empathetic learning and adaptation based on understanding and experience. As these forms of technology – such as autonomous shipping – begin to make major inroads, with observable disruptive impacts on firms and service ecosystems, future research should examine the effects on resource integration. As the boundary between human actors and technology increasingly disappears (Breidbach et al., 2018), the latter is expected to shift even further along the operand–operant resource spectrum, possibly to the extent of achieving agency. As the ramifications of this evolution would further affect the interplay between technology, strong and weak ties, and resource integration patterns, longitudinal research would provide deeper insights into the consequences of such technological shifts.

Note

1. Any similarity to an actual company with this name is purely coincidental.

Acknowledgments

Christian Kowalkowski, Bård Tronvoll and David Sörhammar acknowledge the support of Riksbankens Jubileumsfond (The Swedish Foundation for Humanities and Social Sciences) (research grant number: P15-0232:1).

Disclosure statement

No potential conflict of interest was reported by the authors.

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Funding

Christian Kowalkowski, Bård Tronvoll and David Sörhammar acknowledge the support of Riksbankens Jubileumsfond (The Swedish Foundation for Humanities and Social Sciences) [research grant number: P15-0232:1].

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