2022

Boundary resource interactions in solution networks

Ruiqi Wei

Roisin Vize

Susi Geiger

Received 13 July 2020
Revised 18 January 2021
3 May 2021
10 November 2021
Accepted 1 December 2021

Boundary resource interactions in solution networks

Ruiqi Wei
Department of Marketing, Emlyon Business School, Écully, France
Roisin Vize
School of Marketing, College of Business, Technological University Dublin, Dublin, Ireland, and
Susi Geiger
Department of Marketing, University College Dublin, Dublin, Ireland

Abstract

Purpose – This study aims to explore the interactions between two different and potentially complementary boundary resources in coordinating solution networks in a digital platform context: boundary spanners (those individuals who span interorganizational boundaries) and boundary interfaces (the devices that help coordinate interfirm relationships, e.g. electronic data interchanges, algorithms or chatbots).

Design/methodology/approach – The authors conducted a multiple case study of three firms using digital platforms to coordinate solution networks in the information communication technology and lighting facility industries. Data were collected from 30 semi-structured interviews, which are complemented by secondary data.

Findings – As task complexity increases, smarter digital interfaces are adopted. When the intelligence level of interfaces is low or moderate, they are only used as tools by boundary spanners or to support boundary spanners' functions. When the intelligence level of interfaces is high or very high, boundary spanners design the interfaces and let them perform tasks autonomously. They are also sometimes employed to complement interfaces' technological limitations and customers' limited user ability.

Research limitations/implications – The industry contexts of the cases may influence the results. Qualitative case data has limited generalizability.

Practical implications – This study offers a practical tool for solution providers to effectively deploy boundary employees and digital technologies to offer diverse customized solutions simultaneously.

Originality – This study contributes to the solution business literature by putting forward a framework of boundary resource interactions in coordinating solution networks in a digital platform context. It contributes to the boundary spanning literature by revealing the shifting functions of boundary spanners and boundary interfaces.

Keywords Business-to-business marketing, Solutions, Networks, Digital platforms, Boundary spanners, Boundary interfaces

Paper type Research paper

1. Introduction

Digitalization has become a transformative shaping force of business-to-business (B2B) relationships (Hofacker *et al.*, 2020). New technologies such as supply chain optimization tools and artificial intelligence (AI), for instance, enable companies to optimize their operations and manage their business networks efficiently (Herhausen *et al.*, 2020). These technologies rely on digital platforms, which facilitate streamlined connections between suppliers, business partners and customers and enable smart customer solutions,

European Journal of Marketing
Vol. 56 No. 2, 2022
pp. 532-561

0309-0566
DOI 10.1108/EJM-07-2020-0522

particularly when these solutions are modular in design (Eloranta and Turunen, 2016; Salonen *et al.*, 2018). As a result, solution providers' reliance on human boundary spanners for interfirm coordination – salespeople, account managers or solutions specialists – is greatly reduced, as many of their traditional functions have been taken over by digital platforms. However, the precise implications of digitalization on the roles and functions of boundary spanners have yet to be established in B2B marketing research (Hofacker *et al.*, 2020). Research has also yet to determine how boundary spanners may benefit from digital boundary resources and/or use them for completing or enhancing their tasks. Addressing these issues, this study aims to explore how two different but potentially complementary types of boundary resources – the individuals who span interorganizational boundaries and the interfaces that help coordinate inter-firm relationships – interact in coordinating solution networks in a platform context.

As the employees who build and sustain interorganizational relationships, boundary spanners have traditionally played a particularly important role in customer solution environments (Piercy, 2009; Prior, 2013). Customer solutions are customized combinations of products and/or services that fulfill customer-specific needs (Davies *et al.*, 2007; Evanschitzky *et al.*, 2011; Nordin and Kowalkowski, 2010; Biggemann *et al.*, 2013). In B2B contexts, customer solutions are typically offered through so-called solution networks since solution providers need to obtain resources from diverse business partners to attain service scope and capabilities to fulfill customer requirements (Gebauer *et al.*, 2013; Kindström and Kowalkowski, 2014; Frankenberger *et al.*, 2013; Mason *et al.*, 2012). In these networks, boundary spanners are tasked to manage external relationships (Piercy, 2009) and to connect the different parts of the solution network (Geiger and Finch, 2009). However, their remit often moves beyond these traditional communication functions seen in product markets to more consultative skills including planning internal solution processes, managing risk and coordinating resources (Prior, 2013). They also offer consultation and professional education to customers (Chakkol *et al.*, 2018). Typically, the more customized a solution becomes, the greater the need for boundary spanners' coordination and consultation skills (Tuli *et al.*, 2007).

Boundary spanners and non-human boundary resources have co-existed and complemented each other for a long time; contracts, for instance, have historically first complemented and then substituted verbal agreements between buyers and sellers. Recently, the sheer number, diversity and reach of interorganizational relationships in solution networks, combined with digitalization, have heightened the scope and importance of digital boundary resources (Jonsson *et al.*, 2009; Barrett *et al.*, 2012). For example, B2B online chat functions, social media and AI algorithms now assist in managing B2B relationships and networks (Koponen and Rytsy, 2020; Drummond *et al.*, 2020; Syam and Sharma, 2018), particularly in industries where solutions have become more modular in nature – that is, more flexibly and easily combinable. In the extreme, one could argue that in a fully digitalized and modularized solution network, the roles previously occupied by boundary spanners can entirely be taken over by digital interfaces, making the former redundant. The adoption of new digital technologies such as AI algorithms and chatbots on solution platforms may further accelerate this trend. These technologies are rapidly transforming the functions of interfaces from mere data processing and exchange to subsuming more human-centric tasks such as consulting.

Thus, in digital solution networks, firms are faced with two potentially contradictory tendencies: more focus on customization requiring needs-based interactions and deep knowledge of the customer on the one hand and ever-increasing availability of "intelligent" digital interfaces on the other. We thus argue that there is an urgent need to revisit the respective roles of and interactions between human and digital boundary resources. This paper tackles this task by exploring the interactions between different and potentially complementary boundary resources (that is, boundary spanners and boundary interfaces) in coordinating solution networks. Drawing together insights from the boundary spanners and digital platform literatures, we answer the following research question:

RQ1. How do boundary spanners and digital interfaces interact with each other to coordinate solution networks and how do the roles and functions of the former shift in relation to the increased availability of the latter?

We explore these questions within solution processes in general and more specifically within each phase of the solution process – developing solutions, creating demand, selling solutions and delivering solutions (Storbacka, 2011). Due to the exploratory nature of this study, a multiple case-study approaches was undertaken (Yin, 2003; Eisenhardt, 1989). Three companies that have adopted a platform approach in a solution business context were selected; two are from the information and communications technology (ICT) industry, while one operates in the lighting facility industry.

Overall, this study makes contributions to the solution business literature by putting forward a framework of boundary resource interactions in digital solution settings. The findings show that as task complexity increases, smarter digital interfaces are adopted. When the intelligence level of interfaces is low or moderate, interfaces are only used as tools by boundary spanners or as supports for their own tasks. When the intelligence level of interfaces is high or very high, boundary spanners design the interfaces and let them perform tasks autonomously. They are also sometimes used to complement the interfaces' shortcomings and technological limitations as well as customers' limited user ability. This research contributes to the boundary spanning literature by revealing the shifting functions of boundary spanners and boundary interfaces. We also contribute to the B2B marketing literature by shining a light on the interplay between technology characteristics and employees' capabilities in using digital technologies for firm and network success. Our findings will help managers understand how to deploy different boundary resources throughout a solution process to offer customized solutions efficiently.

2. Theoretical background

2.1 Platform-based networks in solution businesses

Platform thinking suggests that platforms can increase the diversity of offerings while maintaining the same complexity of internal structures (Sawhney, 1998). A digital platform consists of dynamic configurations of tangible resources (technical architecture) and intangible resources (organizational routines, rules and activities) (Perks *et al.*, 2017). Network actors can co-create value by leveraging these resources to innovatively combine products, services and knowledge (ibid.). In this study, we consider a platform approach as a systematic way to reconfigure different modules and module providers by leveraging a modular solution structure and a digital platform. In these platform-based solution networks, the number of suppliers and their diversity typically increases (Choi and Krause, 2006). Relationships begin to diversify as the supply chain is disintegrated vertically and heterogeneity of products and services increases. All of these factors lead to increasing complexity in network coordination. To tackle these recent challenges in solution network coordination, past studies have typically focused either on the role of boundary spanners – sales people, account managers and supply chain managers – or that of digital interfaces, as shown in Table 1. However, where solution providers can use digital platforms to facilitate resource combinations and network reconfiguration (Eloranta and Turunen, 2016;

Table 1. Boundary resources in solution networks

Article	Relevant finding	Research approaches	Interfaces	Boundary spanners	Interactions
Storbacka (2011)	Suggested that interfaces should be clearly defined so that network partners can access the same data about solution delivery in digital platforms	Empirical (multiple case study)	x		
Jaakkola and Hakanen (2013)	Revealed that technology interfaces facilitate component integration processes among solution networks and controlling customer interfaces can lead to advantages in network coordination	Empirical (multiple case study)	x		
Salonen and Jaakkola (2015)	Found that common functional interfaces make external resource integration efficient due to a relatively low degree of coordination and information exchange in business networks	Empirical (multiple case study)	x		
Salonen *et al.* (2018)	Suggested that development of needed technical and interorganizational interfaces underpins a solution platform and facilitates component integration	Empirical (single case study)	x		
Piercy (2009)	Suggested that strategic external relationships (with customers, supplier and partners) should be mirrored in strategic internal relationships (between the functions with lead responsibilities for managing relationships with customers, suppliers and partners)	Conceptual		x	
Geiger and Finch (2009)	Revealed that boundary spanners actively shape industrial networks by making exchanges and forming identities within and across these companies in a network	Empirical (single case study)		x	
Prior (2013)	Found that boundary spanners' activities (communication, planning, risk management and coordination) are important sources of intangible value in complex industrial solutions	Empirical (a netnographic inquiry of online communities)		x	
Prior (2016)	Found that facing tensions in time, resources and information access, boundary spanners adopt consistent behaviors to address customer requirements while reconciling these multiple tensions	Empirical (interviews)		x	
Chakkol *et al.* (2018)	Proposed that in solutions provision boundary spanners' functions evolve into strategic communication, dissonance reduction, professional education, consultation and leveraging offerings	Empirical (single case study)		x	
This study		Empirical (multiple case study)			x

Perks *et al.*, 2017), they also have an opportunity to complement and enhance boundary spanners' roles through these digital interfaces to better coordinate and leverage these large and heterogeneous networks. In the following section, we will detail the traditional roles of these two kinds of boundary resources before exploring how they may interact.

2.2 Interfaces

We broadly define boundary interfaces as those digital artifacts that connect two or more organizations or components in a solution. As shown in Table 1, studies on solution businesses have started to recognize the importance of digital interfaces in integrating external resources (Storbacka, 2011; Jaakkola and Hakanen, 2013; Salonen *et al.*, 2018). However, these studies mainly focus on digital interfaces that facilitate information processing. The growing importance of digital technologies has facilitated the adoption of more advanced digital interfaces to manage relationships in an industrial context. For example, online communities are used to expand organizational boundaries and manage new relationships (Wang *et al.*, 2016). Social media are adopted by B2B companies to engage different network actors (Drummond *et al.*, 2020). Marketing automation systems (such as search optimization and salesforce automation) also help nurture and manage relationships (Mero *et al.*, 2020).

Empowered by AI, new technologies such as chatbots, AI algorithms, web crawling, virtual reality, blockchain and the like have also emerged (Herhausen *et al.*, 2020; Krafft *et al.*, 2020). These new digital technologies can not only process information but also learn from the data, even creating higher-level intelligence to interact with the environment (Krafft *et al.*, 2020). For example, chatbots can help customers gain information faster (Steward *et al.*, 2019) and they can scale up for managing a large number of customer interactions (Luo *et al.*, 2019). Regarding AI algorithms, they "interpret external data correctly, learn from such data and exhibit flexible adaptation" (Kaplan and Haenlein, 2019, p. 17). They perform well-defined tasks with little or no human intervention (Davenport *et al.*, 2020). For example, they are able to gain insights from a large volume of data to provide customers with more customized information in the selling process (Syam and Sharma, 2018) and help forecast customer demand more accurately to improve supply chain management for the selling company (Kumar *et al.*, 2020). These emerging digital technologies may enable interorganizational and digital interfaces to assume more functions in coordinating business networks, which may also impact boundary spanners' functions.

2.3 Boundary spanners

Boundary theory proposes that "a central task of organizations is to manage their boundaries with other organizations that supply critical resource inputs" (Zhang *et al.*, 2011, p. 319). Based on boundary theory, boundary spanners (or boundary spanning employees) are those people positioned between an organization and its external environment; for instance, salespeople, account managers, supply chain managers or other externally facing staff (Aldrich and Herker, 1977; Richter *et al.*, 2006; Stock, 2006). Two key boundary spanning functions were originally put forward by Aldrich and Herker (1977): information processing and external representation. Regarding information processing, boundary spanners bring information from the external environment into an organization. External representation relates to how a firm responds to and interacts with its environment through boundary spanners. Besides external representation, boundary spanners also facilitate trust building (Friedman and Podolny, 1992; Perrone *et al.*, 2003). More recent literature on boundary spanners, particularly in a solution context, focuses on their key capabilities in developing, facilitating and sustaining diverse interorganizational relationships (Zhang *et al.*, 2011). Building on Aldrich and Herker (1977) and Zhang *et al.* (2011), for instance, put forward three key external representation functions:

(1) strategic communication between the firm and its external partners;

(2) professional knowledge, which is the application of knowledge to carry out their responsibility competently; and

(3) the capability to compromise through effective mediation supports.

Beyond information exchange, a boundary spanner can also align divergent interests by establishing a middle ground between actors (Kragh and Andersen, 2009). Research further reveals that boundary spanners can build strong interpersonal relationships, promoting flexibility, solidarity and reciprocity between organizations involved in the solution provision process (Roehrich and Lewis, 2014). Importantly, as solutions become more complex, not only do the communication and coordination functions of boundary spanners become more important, consultative and other highly value-adding skills such as strategic planning also become crucial (Chakkol *et al.*, 2018). Thus, with a move to complex solution contexts, the traditional boundary spanning functions of key account managers or salespeople have expanded. As Zhang *et al.* (2011) point out, the expansion of the functions that boundary spanners fulfill also requires a rethinking of their capabilities.

2.4 Boundary resources in a solution process

Turning to the solution literature, as summarized in Table 1, while rich in insights on how boundary spanners can support interorganizational relationships in solution networks (Prior, 2013; Prior, 2016; Chakkol *et al.*, 2018), studies have often overlooked the impacts of digitalization and automation of interorganizational processes on the functions of boundary spanners in solution provision. These studies have also ignored interactions between boundary spanners and digital interfaces, which deserve more attention, particularly in the context of digitalization, as previously argued. To answer our research question, we investigate how boundary spanners interact with interfaces in a solution process. We hypothesize that the way these two different but complementary boundary resources interact may depend on the specific stage of the solution process. Several different stage models exist in the solution literature. For example, Tuli *et al.* (2007) include customer requirements definition, integration and customization of goods and services and post-deployment support in their four-stage process. Pawar *et al.* (2009) propose a three-stage model including the stages of defining value, designing value and delivering value. Focusing on new service development, Kindström and Kowalkowski (2009) suggest that a solution process includes market sensing, development, sales and delivery. They add a sales phase in the solution process and further indicate that solution providers should find methods to increase efficiency in selling and delivering solutions. To synthesize, these studies focus on understanding customers, solution development, selling and delivery.

While the studies above emphasize selling single solutions, Storbacka (2011) recognizes the importance of creating repeatability and sales efficiency of solutions. He proposes an adjusted four-stage solution process, which consists of: developing solutions, creating demand, selling solutions and delivering solutions. Based on previous studies (Kindström and Kowalkowski, 2009; Pawar *et al.*, 2009), Storbacka (2011) maps out two parallel processes across these four phases, as shown in Figure 1 (customer linking/value building activities and solution development/deployment activities).

In this four-phase solution process, solution providers mainly rely on employees, working methodologies and limited digital interfaces to coordinate the process. As infrastructure support (Storbacka, 2011), enterprise resource planning (ERP) systems and communication interfaces are used to manage the delivery process among network partners in phase four. Databases are also used as knowledge repositories to disseminate knowledge across functions. In other phases, however, solution providers mainly rely on employees to develop and coordinate solution activities manually, for example, collecting information to understand customer value drivers, developing rules for structuring solutions, proposing value to customers and working with industrial associations to create visibility, using working methodologies such as configuration tools to develop specific customer solutions and quantifying the value of the specific solutions for the customers. Thus, while valuable in mapping the complexities of interorganizational coordination in each phase of the solution process, Storbacka's framework does not take account of the respective roles and interactions between digital interfaces and boundary spanners. Yet, with rapid advances in digital technologies and their increasing "intelligence" levels, digital interfaces may have assumed more functions in these coordination activities, which in return changes the functions of boundary employees and the interdependencies between employees and interfaces. Storbacka's (2011) synthetic four-stage model focuses on the repeatability of solutions and selling different solutions efficiently, which is aligned with the platform approach to reconfigure different modules to sell different solutions simultaneously in our study. We thus build on Storbacka's (2011) four-stage solution process to structure our investigation of how boundary spanner interacts with digital interfaces in each of these stages.

3. Methodology

3.1 Case study research

This study adopts a multiple case approach due to the exploratory nature of the research questions (Yin, 2003). Compared with single-case studies, the multiple case approach adds rigor in building overarching theories and enhances external validity of findings, which are grounded in empirical evidence from different cases (Yin, 2003; Eisenhardt, 1989; Gibbert and Ruigrok, 2010). Multiple cases are used to compare and complement individual case insights (Yin, 2003), which leads to a more nuanced understanding through cross-case comparison (Eisenhardt, 1989). This research design was adopted to explore the interactions of boundary resources in a digital platform context. The increasing importance of the Chinese industrial context in digital solution businesses is steadily gaining momentum with researchers (Raja and Frandsen, 2017; Powers *et al.*, 2016). Therefore, a Chinese directory of digital platforms relevant to B2B solutions was used to source suitable firms.

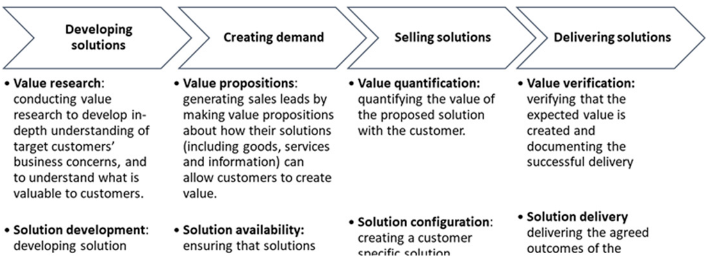

Figure 1.
Solution process framework, adapted from Storbacka (2011)

Our research followed a purposive sampling approach (Eisenhardt, 1989; Patton, 1990), which allows researchers to identify cases with rich information related to the research topic in question. Based on the criteria developed through the literature and our research objective, we contacted companies via e-mail or phone call to explore their suitability and interest in participating in this study. The following criteria allowed us to identify applicable case companies relevant to the study:

- Firms had to operate business models that represent the digital platform phenomenon. This means that at the offering level, these firms rely on a modular structure to reconfigure different products, services and knowledge into a customized solution package (Eloranta and Turunen, 2016; Salonen *et al.*, 2018). At an interfirm level, these solution providers use digital platforms to connect different business partners in the solution networks (ibid.).
- Firms also use digital tools to coordinate these business partners, such as electronic data interchanges (EDIs), information systems and algorithms, which is relevant to our objective to explore digital interfaces and their interactions with boundary spanners.

Three companies headquartered in China were selected, as highlighted in Table 2. They are in two different industries: the ICT industry and the lighting facility industry. The industry differences increase the external validity of our findings (Yin, 2003). Aligned with similar prior studies (Eloranta and Turunen, 2016), in these selected companies, data collected through EDIs embedded in the digital platforms enable them to identify modules and develop new solutions. Algorithms embedded in the digital platforms match modules with customer requests to customize solutions. Data centralized in information systems from network actors also assist employees in mobilizing resources to deliver solutions. The case firms thus provided a relevant setting to investigate the interactions between digital interfaces and boundary spanners. The companies are anonymously referred to as Light1, ICT1 and ICT2. Table 2 provides an overview of all case companies and their business characteristics. Further information about these firms is provided in Section 4 case background.

3.2 Data collection

The research process consisted of two phases. The first phase was conducted from July to August 2016 as part of a broader research study (Wei *et al.*, 2019). In this phase, 22 semi-structured interviews were conducted (a further eight interviews were conducted in phase two, as detailed below). The interviews lasted from approximately 30 to 100 min. The option of using semi-structured interviews was consistent with our aim of theory building and offered us the flexibility to include the topics and concepts that we might have missed (Patton, 1990). To gain a deeper insight into the companies' context, business models and platform designs, we interviewed senior executives from different departments within the organizations, as detailed in Table 3. These interviews enabled us to gain an understanding of the overall picture of the solution process from the firm's perspective. We also conducted interviews with managers focused on how the solution providers to design and use their platforms to manage the interactions among module providers and customers in each solution phase. The interviewees included managers responsible for different phases in a solution, such as supply chain, operations, community and printed circuit board (PCB) managers. During this research phase, the importance of boundary spanners and their interactions with digital interfaces emerged, which prompted us to review the literature on boundary spanning and interfaces. To complement the interview data, we collected data

Companies	Business characteristics	Boundary resources
ICT2	Transformed from a PCB manufacturer originally, ICT2 offers end-to-end solutions comprising electronic components and assembling services on its digital platform based on its PCB business. It manages an online community for customers to acquire industrial knowledge	*Boundary spanners:* Supply chain employees, customer service employees, technical consultants, online community employees *Interfaces:* Online forms, automatic module reconfiguration algorithms, online community (webinars, online forums, broadcasts), EDIs, web scraping bot, information systems
ICT1	As an industrial service company, ICT1 offers a wide range of modules in its solutions, such as PCB manufacturing and electronic components assembling Engineering design optimization is also offered by ICT1 due to its partnerships with leading databases It also manages an online community where customers can acquire industrial knowledge	*Boundary spanners:* Operations employees, customer service employees, technical consultants, online community employees *Interfaces:* Online forms, automatic module reconfiguration algorithms, online community (webinars, online forums, broadcasts), chatbot, EDIs, web scraping bot, information systems
Light1	As an industrial service company in the lighting facility industry, Light1 develops lighting plans as solutions for property developers It uses its digital platform to organize diverse component suppliers, designers, engineering firms, standard testing firms to provide these solutions	*Boundary spanners:* Supply chain employees, customer service employees, trading employees, technical consultants, account managers *Interfaces:* Online forms, EDIs, automatic module reconfiguration algorithms, information systems

Table 2.
Case companies and business characteristics

from the firms' websites and digital platforms, such as the designs of information systems, digital contracts, digital forms, process descriptions posted online, to understand the use these companies made of boundary resources.

The second phase of interviews was conducted between June–July 2018 with directors and executives focused on the design and the interactions of the functions of boundary resources in the overall processes and the rationale for decision making. Follow-up interviews with managers were conducted if additional information was needed or based on executives' suggestions. To seek an external perspective, we also conducted interviews with several key customers chosen by the companies in research Phase 1 or research Phase 2, which enhanced the internal validity of our findings (Gibbert and Ruigrok, 2010) (see Appendix 1 for the interview guide). The first author, who is fully bilingual, transcribed and translated the digitally recorded interviews for analysis. To verify accuracy, the transcripts were sent back to the interviewees to review and amend if necessary (Lindgreen, 2008).

Archival records and internal firm documents about stakeholders such as module providers were collected to supplement interview data. Such documents included product books, process descriptions, quality management procedures, customer feedback, contract

Case companies/ industry	No. of employees	Interviewee job title and numbers of interviews per interviewee
ICT2 (ICT industry)	340	13 interviews: RESEARCH PHASE ONE Chief Operations Officer (1) CEO (1) Online Community Manager (1) Supply Chain Manager (1) PCB Manager (1) Customers (2) RESEARCH PHASE TWO: Chief Operations Officer (1) Vice President (supply chain) (1) Vice President (PCB) (1) Customer Service Supervisor (1) Customer (1) Supply Chain Manager (1)
ICT1 (ICT industry)	93	10 interviews: RESEARCH PHASE ONE Operations Director (2) PCB and Supply Chain Manager (2) Operations Manager (1) Online Community Manager (1) Customers (3) RESEARCH PHASE TWO: Operations Director (1)
Light1 (Lighting facility industry)	115	7 interviews: RESEARCH PHASE ONE Operations Director (2) Operations Manager and Operations Director (1) Supply Chain Supervisors (1) Key Account Manager (2) RESEARCH PHASE TWO Operations Director (1)

Table 3. Interviewees and job roles

templates, regulations, as well as screenshots from websites to identify the functions of the interfaces. Observation notes were also taken in a research diary during the fieldwork, for instance, when studying the digital boundary interfaces. These different kinds of data collected allowed us to maintain a clear chain of evidence from the empirical data to the final analytical framework (Yin, 2003).

3.3 Data analysis

Aligned with similar prior studies (Storbacka, 2011; Kindström and Kowalkowski, 2009), our unit of analysis is the solution process, due to our focus on how digital interfaces and boundary spanners interact in different solution phases. Adopting a solution process framework as our research framework also enhances the internal validity of our findings (Gibbert and Ruigrok, 2010). To gain an in-depth understanding of current processes, thematic analysis was used on all data, supported by the software NVivo 11 (Miles and Huberman, 1994). A systematic data reduction process was conducted following Miles and Huberman's (1994) recommendations. When segmentation and coding began, a list of preliminary codes was applied to help us integrate the data with theoretical concepts from extant literature on boundary spanning and interfaces. During the coding process, inductive codes were developed to complement the deductive codes (Appendix B).

Following the solution process framework (Storbacka, 2011), these codes were subsequently merged into higher-order topics (the functions of boundary spanners and interfaces) in each solution phase. The interactions between the functions of boundary spanners and interfaces in each solution-phase were analyzed across interviews, documents, archival records and screenshots in each case. Then, under the solution process framework, we mapped out boundary spanner functions and interface functions as well as their interactions in each solution phase for each case.

3.3.1 Cross-case analysis. To compare and contrast the solution processes, cross-case analysis was applied (Eisenhardt, 1989). The functions of boundary resources and their interactions in each phase were compared across cases and solution phases. Through cross-case analysis, we noted the similarities in their functions and in their interactions across cases and solution phases. This gave rise to the notion that the same type of interactions across cases may share similar contingencies. Through comparing different types of interactions across cases and solution phases, we identified three contingencies, which are:

(1) user ability;
(2) intelligence level of the interface; and
(3) task complexity.

User ability is defined as having the necessary knowledge and skills to use the interface (Meuter *et al.*, 2005). Intelligence level relates to the technological capabilities of the interfaces, that is, the interface's technological ability to process more autonomous and complex actions (Hancock *et al.*, 2011; Glikson and Woolley, 2020). Task complexity refers to the level of analytical thinking required for a task (Gupta *et al.*, 2013). Based on these definitions, we assessed the levels of these constructs for different types of interactions in different cases (Table 4). By analyzing their similarities and differences across cases, we put forward a framework of boundary resource interactions as per Figure 3.

To increase reliability and transparency, we built a case database which includes the interview transcripts, the documents, observation notes and analysis (Yin, 2003). To improve data quality, we triangulated our findings across different data sources (Creswell and Miller, 2000). This also ensured construct validity in our study. For example, the interview transcripts were compared with our observation notes and process description documents, which helped examine consistency among them. Further questions were asked to the interviewees for explanations of any inconsistency. We also ensured that our interviewees had sufficient familiarity with the solution process by asking initial interview questions to evaluate their experience (Miles and Huberman, 1994). To validate the findings and ensure internal validity, the findings were sent back to key informants who agreed that the findings were valid and recommended small modifications, for instance, technical terms in the service processes (Lindgreen, 2008).

4. Case background

The following section provides details on the three case companies used in this study. Light1 is in the lighting facility industry and provides customized solutions as lighting plans to key buyers such as property developers. The solutions offered by Light1 include different offerings, such as solution planning services (choosing products and lighting design), product development or purchasing, accreditation services and implementing the

Table 4. Cross-case analysis

Solution phase	Interface	Interface function	\span 4–5 \Intelligence level	Task complexity	User and user ability	Boundary spanner	Function	Boundary resource interactions	Company
Phase one (developing solutions)	The automatic module reconfiguration algorithms	Automatic module reconfiguration; optimization	Very high (expected)	Very high (expected)	Customer, high user ability	Technical consultants and supply chain/ operations employees	Strategic planning	Boundary spanners design interfaces	Light1 (without optimization), ICT1, ICT2
	Web scraping bot	Data gathering and synthesis	Moderate	Moderate	Employee, low user ability	Technical consultants and supply chain/ operations employees	Strategic planning	Interfaces support boundary spanners	ICT1, ICT2
Phase two (creating demand)	Webinars, online forums and broadcasts	Knowledge sharing	Low	Low	Employee, high user ability	Online community employees	Community building	Boundary spanners use interfaces	ICT1, ICT2
Phase three (selling solutions)	The automatic module reconfiguration algorithms, Chatbot (ICT1 only)	Automatic module reconfiguration; optimization	High	High	Customer, low user ability	Account managers or technical consultants	Consultation	Boundary spanners complement interfaces	Light 1 (without optimization), ICT1, ICT2
Phase four (delivering solutions)	EDIs	Network communication	Moderate	Moderate	Employee, low user ability	Supply chain/ operations employees	Resource mobilization	Interfaces support boundary spanners	ICT2, ICT1 (partly), Light 1 (partly)

lighting plan. On its digital platform, customers can match their needs with relevant products and services by uploading or entering their requests. The algorithms embedded in the platform automatically match these requests. Customers can also select products and services showcased on the platform. They can contact a consultant online when they require support. Light1 uses payment tools, communication tools and information sharing tools on the digital platform to coordinate the activities in the solutions, such as components purchase, product development, design services and standard testing services. Customers can monitor parts of the solution process since information sharing is enabled on the platform.

ICT1 is in the ICT industry. It offers end-to-end solutions to engineering firms to help develop new products. Their solutions comprise different processes, including developing or purchasing components, optimizing design, manufacturing sample products and testing standards. It resells components including motherboards, printed circuit boards and research and development (R&D) tools through its digital platform. Component assembling services are also offered to its customers. Customers can upload a list of components and their designs so that the algorithms can automatically match component providers and service providers for them. Partnering with a components database, ICT1 offers data analytics to its customers to optimize their product designs. With an online community on its digital platform, customers can gain advice and knowledge from technical experts and interact with each other. Communication and payments tools are embedded in the digital platform to manage transactions. Information sharing is enabled on the platform to help customers monitor parts of the solution process. Chatbots are used to answer frequently asked questions raised by customers.

ICT2 also operates in the ICT industry. Originally a PCB manufacturer, ICT2 has developed into a solution provider offering end-to-end solutions for new product development. Its solution processes include purchasing components, customized component development, PCB design, component assembling and standard testing. It resells different components and tools to its customers on its digital platform, such as motherboards, capacitors, sensors and R&D tools. Customers can upload their lists of components and their designs so that the algorithms on the platform can automatically match the service providers and the component suppliers for them. Design optimization is also a function of the algorithms, which can help customers replace their chosen components with more suitable ones. ICT2 coordinates these modules and business partners with its digital platform where payment and communication tools are embedded. Information sharing is also enabled so that customers can monitor the whole solution process. ICT2 also manages an online community on its digital platform where customers can interact with technical experts and with each other.

5. Findings

The solutions literature typically recognizes a phased approach in the solution process. Our findings are presented following Storbacka's (2011) solution process phases. These are:

- developing solutions;
- creating demand;
- selling solutions; and
- delivering solutions and adapting the two parallel activities, that is, customer linking/value building activities and solution development/deployment activities, as per Figure 1.

Our findings extend this framework by discussing the functions of boundary spanners and interfaces in a platform context and, more importantly, by considering their interactions and the contingencies of these interactions during each phase. In keeping with the methodological approach, we highlight similarities and differences between our three case companies as summarized in Table 4, which reveals the interfaces and boundary spanners, as well as their functions in each solution phase in the case companies. The table also includes the interactions between boundary spanners and interfaces as well as three contingencies of these interactions, intelligence level, task complexity and user ability. Our theoretical framework is presented in Figure 3.

5.1 Phase one: developing solutions

Solution providers create a solution portfolio by combining customer insight and provider resources (Storbacka, 2011; Kindström and Kowalkowski, 2009; Pawar *et al.*, 2009). For value research in this phase, boundary spanners perform their strategic planning function to gather customer data about customer perceived value. The data help them decide how to develop or include new modules in their solution networks. Different from the offline context, technical consultants and customer service employees in all three companies analyze the usage records of the existing module reconfiguration algorithms to determine trends and those modules that customers consider most valuable. Since customers are many and very diverse in a platform context, analyzing these algorithmic usage records has made data gathering more efficient. The data are also complemented by feedback from online surveys, aftersales calls and online reviews, as revealed by the records we collected.

> "[[. . .]] we use insights to drive the development of the company's strategy [. . .] We have our own foundation, a large amount of data, the user data and we can get insights into what is needed through data analytics. Analyze what he [the customer] needs from the perspective of big data and then provide customized services." (Chief Operations Officer, ICT2)

While Light1 mainly relies on internal data, ICT1 and ICT2 conduct research on competitor performance, including sales data and prices. Rather than using traditional research methods, technical consultants gather these competitor data by using web scraping bots to scan competitors' websites or platforms so that they understand the market dynamics and identify potential module providers. Web scraping bots automatically collect and synthesize large amounts of competitor data. These interfaces suffice for these tasks since task complexity is moderate, which means these tasks only involve some analytical thinking, such as data synthesis. However, the web scraping bots can only perform these tasks with some human interventions and without advanced technological capabilities to further analyze the data, so their intelligence levels are moderate. Boundary spanners only need low user abilities to use these interfaces, as these interfaces automate some parts of the data gathering and synthesis process and they have greatly facilitated value research.

Based on the data gathered in value research, boundary spanners then develop solutions. The diversity of modules and module providers on the digital platforms prompts boundary spanners to use the data to develop algorithms for automatic module reconfigurations rather than developing working methodologies for configuring modules manually. To develop these algorithms, EDIs are used for connecting platforms' information systems with those of module providers for data sharing. To decide which module providers should be connected, supply chain/operations employees in all three companies contact module providers and gather further information about their modules and capabilities, such as module features and usage occasions, production plants and qualifications. This module information is also shown in our collected product books.

> "Since it became our supplier, we've checked [. . .] its size and qualification, or the quality of the product, which means he's already in control of our supply chain. Then his product [. . .] must meet our requirements before it could enter our supply chain system." (Supply Chain Supervisor, Light1)

If the results detect suitable capabilities, EDIs are offered to connect the suppliers with the platforms' information systems. Supply chain/operations employees also use the systems to categorize module providers according to their product categories, expertise, reputation, delivery time and so on, which becomes the foundation for the algorithms for module matching. With the support from their technical support teams, they also link these data with those from other departments, such as finance, operations and logistics, which, in turn, allows developing an algorithm to predict the instant final price for each module for the customers.

> "When you have a lot of orders, standard software cannot calculate them (the final prices), you have to develop your own algorithms to do it, such as the costs, the fees and the logistics, all of them need to be included in the calculations" (Supply Chain Manager, ICT2).

Thus, the value for solution development can be quantified by the algorithms. The algorithms can also identify similarities among modules and module providers and combine similar orders to lower the cost for the module providers and the customers. A ranking algorithm is developed, which ranks module providers dynamically based on their up-to-date performance, thereby optimizing the solution quality for the customers. Consistent with the interviews, our observations of ICT2's platform reveal that the algorithms also help customers improve their solution design by recommending better modules, an issue we will further discuss in phase three. Solution providers externalize the algorithms for customers to use in phase three to automatically match customer requests with the most suitable modules and module providers. As such, these algorithms can increase efficiency and lower labor cost in module reconfiguration due to their expected high intelligence level to perform these tasks independently for customers. These algorithms can suffice for these tasks with a high intelligence level even though task complexity is very high (that is, it involves a lot of analytical thinking). The algorithms analyze customer requests and module providers' information, then match and recommend customers with modules with technical suitability and better service performance. However, solution providers also recognize that customers using these algorithms independently need to have high user abilities, as customers need to understand and evaluate the results produced by these algorithms. This requires solution providers to deploy boundary spanners to offer support to the customers with lower user abilities, which will be further discussed in phase three.

Thus, phase one findings reveal that boundary spanners have become interface designers; that is, they design high-intelligence interfaces such as automatic module reconfiguration algorithms. Additionally, interfaces with moderate intelligence levels such as web scraping bots support boundary spanners' strategic planning function by automating data gathering and data synthesis processes.

5.2 Phase two: creating demand

Solution providers communicate the available solutions so as to identify sales opportunities (Storbacka, 2011; Kindström and Kowalkowski, 2009). In phase one, solution providers have connected information systems with module providers to ensure solution availability; now, they need to build value propositions about how customers can use modules to create value. For proposing value, rather than deploying sales to develop relationships with individual customers and working with industry associations to create visibility (Storbacka, 2011), our case companies rely on their online communities to generate sales leads. For example, ICT1 and ICT2 manage online communities on their digital platforms, while Light1 uses social media applications to build their communities.

> "When customers log into our online community, they would bring along their demand. For example, they exchange ideas on products and designs and we have corresponding offerings to serve them." (CEO, ICT2)

In our study, an online community and other community communication tools such as webinars, forums and broadcasts are considered digital interfaces. Employees managing an online community are considered as boundary spanners. The interface function is knowledge sharing while boundary spanners use these interfaces as tools to perform the community-building function. The intelligence level of these interfaces is low since they require limited technological capabilities and limited analytical thinking (that is, low task complexity) and they cannot process information to solve problems without human intervention. While these interfaces only serve as channels for knowledge sharing, boundary spanners intervene to use these interfaces to facilitate and leverage knowledge sharing and interactions. They build up a virtual community to foster trust and share knowledge above and beyond what would happen if the boundary interface was left to run itself. Thus, while interfaces with low intelligence levels are sufficient for information sharing tasks, boundary spanners' abilities become important because they need to understand how to use these interfaces to perform various tasks in the online communities; the user ability for these interfaces is therefore high.

For proposing value to customers, in the online communities of ICT1 and ICT2, online community employees hold webinars with module providers to share knowledge about their new modules. Skills needed to hold these webinars include technical skills to use the webinar tools and coordinating skills in hosting webinars. Sharing knowledge through webinars provides suggestions to customers about how the solution offerings (including products, services and information) allow them to create value.

> "When a manufacturer (module developer) initiates a webinar, we call for customers' engineers to sign up. For example, the first session is about technical knowledge. We ask the engineers to participate, listen online and communicate with each other, including online interactions, online lectures, chat boxes to ask questions and the manufacturer arranged their engineers to answer." (Community Manager, ICT2)

Online community employees in ICT1 and ICT2 also use their online forums to distribute new module samples to customers' engineers and encourage them to post their experiences in the forums. These reports and samples show insights into the new modules and further convince the customers of the modules' value, as demonstrated by the reports we gathered. To launch these events successfully, online community employees use their knowledge to decide what new module samples will be distributed, who receives the samples and which reports will be shared; this cannot be done by the interfaces.

> "(To decide who receive the samples,) we will evaluate the application materials they submit. For example, they need to describe in detail how they will use the sample module. We also examine their technical backgrounds to see whether they have the abilities to use the sample modules." (Community Manager, ICT2)

Consistent with our interviews, our observations of the online communities show that online community employees also use the online forums to encourage interactions by creating topics about how to integrate new modules. They evaluate the topics that will be valuable to customers based on their knowledge levels and the interactions on the topics can demonstrate how to use these modules to create value. More importantly, online community employees enhance customer trust in solution providers through community building.

> "The online community builds up trust in customers' minds. Once a reliable and trustworthy relationship is built up, conflict between customers and providers can be avoided. If a community is integrated into a digital platform, this trust can be considered as a safeguard (in transactions)"(Customer S, ICT2)

However, since Light1 maintains its community via social media applications, it only posts promotional content in these channels, indicating a lack of knowledge sharing in this process.

Phase two finds that while interfaces with low intelligence levels serve as channels for knowledge sharing, boundary spanners need to have high user ability to deploy these interfaces effectively to convince customers how modules and solutions can allow them to create value.

5.3 Phase three: selling solutions

Solution providers engage customers in a process to help them specify their solutions (Storbacka, 2011; Kindström and Kowalkowski, 2009; Tuli *et al.*, 2007). In this phase, for solution configuration, rather than relying on working methodologies to configure solutions for customers, solution providers offer customers the use of automatic module reconfiguration algorithms developed in phase one. These algorithms can automatically reconfigure different modules and match customers' requests with their supplies or services. For example, in ICT2, these algorithms can automatically finish 60%–70% of matching in a customer request. When the levels of modularization are high and there are diverse modules, automation of this matching process reduces the need for human intervention, thereby enhancing accuracy and efficiency in this process, as the following quote indicates:

> "For this part (the algorithms), [. . .] we have made use of our millions of data, based on the types, the properties and even one parameter (of a product module), when you are looking for it (the product module), we can match it (for you)." (Supply Chain Manager, ICT2)

Customers can use them easily by submitting requests or by entering the properties or parameters of the requested products. For service modules, the algorithms can also help identify the most suitable service module providers – that is, those whose service processes lead to the shortest delivery time. When placing orders, customers indicate different requests, such as lowest cost or shortest delivery time. Based on customer requests and module providers' performance in key dimensions, such as quality control, production capacity, payment period and production stability, the algorithms rank module providers and match customer requests. Module providers ranked first will receive a large percentage of the orders, with the second-ranked providers assisting the first rank to complete the rest of the orders. Thus, the algorithms optimize the solution process. The algorithms developed by ICT1 and ICT2 not only automatically match customer requests with product modules but also offer optional modules for customers to switch. This is related to the optimization function of interfaces. The optional modules have similar parameters compared to what customers are looking for; however, they can lead to shorter delivery time, lower cost or better performance.

> "For example, some peripheral components can be replaced. Supplier A and Supplier B both have the same type of components, but their prices and the technical performances are different. Our system will recommend our customers to switch." (CEO, ICT2)

For value quantification, the algorithms predict results in terms of the delivery time, the cost and the performance level of the requested modules due to data linking across departments. As such, the solution providers do not need to rely on business control employees to support sales teams by manually calculating the data for each solution. Additionally, in partnership with a large industry database, the algorithms in ICT1 also provide further information about product modules, such as product lifecycle, compatibility and price fluctuation. By sharing these data in the matching results, the algorithms quantify the value of the solutions and identify risks for the customers. Therefore, the intelligence level of these algorithm interfaces is high, as they analyze customer information and module providers' information to automate most of the module reconfiguration process. With high intelligence levels, the algorithm interfaces can complete tasks that involve much analytical thinking (that is, high complexity), such as analyzing customer requests, analyzing module features and optimizing the design.

However, the interfaces are not intelligent enough to solve all customer problems, especially when the requested modules are very specialized. Human intervention is still required. Additionally, even though the ordering process has been automated, a customer without enough technical knowledge or abilities (that is, low user abilities) has to consult with technical consultants about what modules to include in a solution. These customers may not have the knowledge and the abilities to interpret the results created by the algorithms, such as product lifecycle, compatibility and technical performance. In ICT1, a chatbot is used to answer customer questions. The chatbot provides relevant information to customers straight away and directs them toward relevant web pages or functions. When a chatbot cannot answer the questions, especially when a customer is looking for non-standard or highly technical modules, it will recommend the customer to consult with a technical consultant, which is also demonstrated by our observations.

At this point, a technical consultant, as a boundary spanner, will perform the consultation function to identify and solve customer problems with their knowledge and expertise. They also help customers select modules and represent module providers to recommend modules. By doing so, boundary spanners complement the limitations of the chatbot and the algorithms.

> "When the customer orders, he can consult by clicking the 'consultation' button on the web and we will have corresponding members communicate with him [. . .] .For example, the customer may ask something like, what is the technical performance of the module? Can this module do something like this for me?" (Vice President, ICT2)

Therefore, in this phase, while interfaces have high intelligence levels to solve highly complex tasks such as module reconfigurations, they are constrained by their own technological limitations and customers' user abilities. Boundary spanners thus need to complement the shortcomings of these interfaces to help customers solve problems with their knowledge and expertise.

5.4 Phase four: delivering solutions

In the final phase, a solution provider delivers the solution, thus securing the value created for their customer and capturing value for themselves (Storbacka, 2011; Kindström and Kowalkowski, 2009; Pawar *et al.*, 2009). As solution providers need to deliver many modular solutions simultaneously, they rely on interfaces to facilitate instant information transfer among network actors to monitor the delivery processes. The interfaces here represent digital devices for data sharing, for example, EDIs, information systems and online forms.

For both value verification and solution delivery, these interfaces perform network communication to facilitate information sharing among different module providers and customers. For standardized modules, while the algorithms have automated the module development and delivery processes, network communication enables process monitoring and results verification. In ICT1 and ICT2, the information systems can inform boundary spanners of the risks in the process so that they can switch potentially problematic module providers with another within the same ranking. As such, the value created to the customers can be secured and verified regularly.

Customer requests of non-standard or highly specialized modules cannot be matched by the algorithms. The interfaces (EDIs, information systems and online forms) offer standardized means to exchange information to reduce variety in the information flow transferred among different business partners. In all three cases, our analysis of digital forms shows that different parameters are used on these digital interfaces to help customers submit and structure their special requests, so that module specification is possible.

> "When placing the order, a customer has the parameters to choose (in the system), such as length and width, spacing between width, depth of drilling. Special requirements must be recorded and we use these to check (the requests)." (PCB manager, ICT2)

Interfaces such as information systems and digital forms centralize and synthesize data in a structured format, which allows boundary spanners to identify similarities in specialized modules. The complexity of this task is moderate since it only involves some analytical capabilities such as data centralization and data synthesis. Thus, interfaces with moderate intelligence levels suffice since they only need to support boundary spanners by automating data gathering and synthesis. This allows boundary spanners to match special modules much more efficiently.

Based on these synthesized data, boundary spanners, such as supply chain/operations employees, mobilize resources by integrating or dividing orders among network actors with a view to achieving economies of scale and scope for these special modules. Instant data about the availability and inventories of module providers are also shown in the information system. For example, in all three cases, product suppliers share their inventory data with solution providers by connecting their ERP systems with solution providers. Industrial service providers also show their availability on the systems, according to our observations. This information supports boundary spanners in assigning special orders to suitable module providers in a timely and efficient manner. Since the interfaces have automated some procedures such as data gathering, data centralization and data synthesis, boundary spanning employees only require relatively low user abilities.

The final phase finds that interfaces such as EDIs, information systems and online forms automatically collect, centralize and synthesize module providers' data, which supports boundary spanners in combining and assigning similar orders to suitable module providers. Instant information sharing also enables boundary spanners to make decisions efficiently. As such, the network communication function supports boundary spanners to make timely decisions on resource mobilization in a network to secure value created for the customers.

5.5 Toward a framework of boundary resource interactions in a digital platform-based solution process

Based on the findings above, we put forward a framework of boundary resource interactions in platform-based solution processes (Figures 2 and 3). Four types of interactions between boundary spanners and interfaces have been identified in the solution process. The first type of interaction is that boundary spanners use interfaces as tools to perform their functions. For instance, in online communities, webinars and forums facilitate knowledge sharing and boundary spanners use these tools to build up online communities to propose value and create demand. The second type of interaction is that interface functions support boundary spanner functions. The interface function of network communication supports boundary spanners in performing resource mobilization and detecting issues in advance. Web scraping bots support them in collecting and synthesizing data from competitors' websites. EDIs and information systems collect, centralize and synthesize different data to support boundary spanners' decision making. The third type of interaction is that boundary spanners complement the shortcomings of interfaces. For example, when customers do not

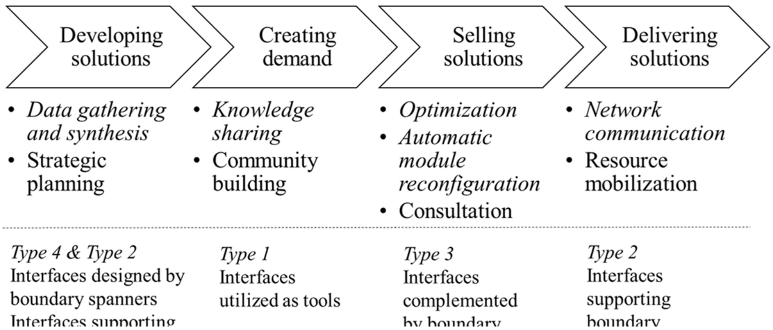

Figure 2.
Framework of boundary resources in solution processes

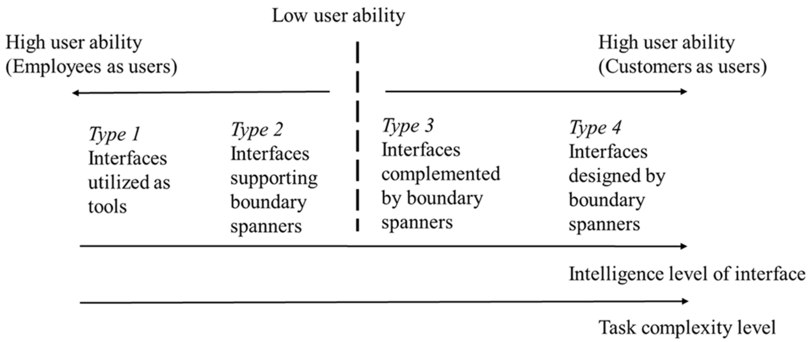

Figure 3.
Framework of boundary resource interactions

have enough expertise or have special requests, boundary spanners will intervene by offering consultation to the customers. When chatbots cannot solve customers' problems, human services are offered. The fourth type of interaction is that boundary spanners design and improve interfaces. For example, through strategic planning, boundary spanners design algorithms to reconfigure modules and optimize solution processes, that is, automatic module reconfiguration and optimization. Ideally, in Type 4, interfaces complete the tasks for customers without boundary spanner interventions.

Our findings further reveal three types of contingencies for these interactions: task complexity level, intelligence level of interfaces and user ability (Figure 3). From Type 1 to Type 4, as task complexity increases, solution providers need to adopt smarter technologies to handle complexity, moving from using digital interfaces to simply share knowledge in online communities to using information systems or web scraping bots to gather and synthesize different sources of data for supporting decisions making and further to using AI technologies such as algorithms and chatbots to automate module reconfiguration and optimization processes. Therefore, as task complexity increases, the "intelligence level" of interfaces also needs to increase significantly. However, user ability influences the effectiveness of these interfaces. When comparing Type 2 with Type 1 where service processes are still internalized, we find that boundary spanners as users of the interfaces need lower user abilities in Type 2 since interfaces are smarter and assist in automating and simplifying some parts of the task (e.g. instantly gathering and synthesizing module providers' data). In Type 3 and Type 4, where service processes are externalized (i.e. customer self-service), more skills are required from the customer's side, especially in Type 4, where processes have the highest intelligence level. In Type 4, only when either customer has high enough user abilities or the interface is intelligent enough can customers use the interface to complete a complex task independently without boundary spanner intervention.

6. Discussion

This research sets out to explore the interactions and synergies between two types of boundary resources – interfaces and boundary spanners – in solution businesses that use a platform approach. We identified different functions of boundary interfaces and spanners in this context; interface functions include data gathering and synthesis, knowledge sharing, network communication, automatic module reconfiguration and optimization, while the functions of boundary spanners include strategic planning, community building, resource mobilization and consultation. Based on these functions, we put forward a framework to reveal four types of interactions between boundary spanners and interfaces. As task complexity increases, smarter digital interfaces are adopted. When the intelligence level of interfaces is low or moderate, they are mainly used as support tools by boundary spanners. When the intelligence level of interfaces is high or very high, boundary spanners design the interfaces and let them perform tasks autonomously. This framework points out the contingencies of these interactions: user ability, intelligence level of interfaces and task complexity. Our findings thus reveal multiple shifting and interrelated functions of interfaces and boundary spanners.

With these findings, we extend current knowledge about interfaces and boundary spanners, especially in the context of digitalization, where digital platforms are implemented to coordinate complex B2B networks and where firms deploy interfaces and employees to coordinate their business partners. It is nearly impossible in a large and modularized business network to rely only on boundary spanners to manage networks and reconfigure modules. Our research shows that human and digital boundary resources can complement each other in important ways – but using both types of boundary resources require careful integration and design.

The findings above make several significant contributions to the literature on solution businesses. Firstly, where prior solution business literature only focuses on the functions of boundary spanners and interfaces independently (Chakkol *et al.*, 2018; Prior, 2013; Salonen and Jaakkola, 2015; Salonen *et al.*, 2018), we highlight the interactions between boundary spanners and interfaces. Based on these findings, this research further reveals four types of interactions between boundary resources and identifies the contingencies for these interactions (task complexity, intelligence level of interfaces and user ability). Our findings also add to the solution process literature (Storbacka, 2011; Kindström and Kowalkowski, 2009; Tuli *et al.*, 2007) by demonstrating that digital interfaces have now assumed more advanced functions in a solution process, such as market sensing (data gathering and synthesis), consultation, optimization and module reconfiguration, which were previously occupied by boundary spanners. This implies a changing focus of boundary spanners from operations to designing and complementing digital interfaces as digital interfaces become more and more intelligent. Therefore, this research offers insights into how boundary spanners and interfaces interact, points out the contingencies of these interactions in the digital solution context and signals how their respective roles evolve.

Second, this research contributes to boundary management literature. While previous studies have mainly focused on information sharing as the function of boundary interfaces (Salonen and Jaakkola, 2015; Salonen *et al.*, 2018), this research highlights more advanced functions such as automatic module reconfiguration and optimization. These functions are the consequences of firms adopting AI technologies in their customer and partner management, such as chatbots and algorithms. In the boundary spanning literature, while Chakkol *et al.* (2018) have endeavored to identify the functions of boundary spanners in solution networks, they have ignored the impacts of digital technologies. Our results demonstrate that the functions identified by Chakkol *et al.* (2018), such as communication, leveraging offerings and consultation, are now being replaced by interfaces carrying out automatic module reconfiguration and optimization. With this, boundary spanners are freed up to become designers and strategic planners, designing the algorithms used in automatic module reconfiguration and optimization and their underlying logical reasoning. However, when these algorithms are not intelligent enough to solve problems in some special cases, boundary spanners will complement the limitations of these algorithms by performing their conventional functions such as leveraging offerings and consultation.

Finally, our research contributes to the broader B2B marketing literature by signaling some of the challenges of adopting digital technologies in B2B marketing. Recent research mainly focuses on the benefits of new digital technologies, such as AI algorithms in demand forecasts (Kumar *et al.*, 2020) and chatbots in customer purchases (Luo *et al.*, 2019). Other researchers call for attention to the role of employees in this digital transformation and to potential negative consequences when digital interfaces start to interact with customers independently (Herhausen *et al.*, 2020). With the *locus* of control shifting to boundary interfaces, new risks may arise as technologies have inherent limitations. Responding to this call, our research indicates that more attention needs to be paid to the interplay between technology capabilities and employees' management and innovation skills to use these technologies and leverage human skills successfully. Our research details the skills required from boundary spanning employees (boundary spanner functions) and the technology feature (intelligence level) that may influence this interplay. With these findings, we point out a new research direction to focus on the interplay between human and digital technologies in B2B marketing.

7. Managerial implications

Digitalization has driven solution providers to adopt more and more digital technologies to manage multiplying boundary interactions. Solution providers need to carefully evaluate how they design and integrate boundary employees and digital interfaces when they deploy these boundary resources. From a managerial perspective, our findings help solution providers consider the contingencies for boundary resource interactions so that they can better design and integrate these resources. As task complexity increases, solution providers need to adopt more highly intelligent technologies. By assessing the intelligence level of digital interfaces, such as algorithms, chatbots or information systems, they can decide how boundary employees such as technical consultants and account managers can work with these technologies. For example, when the intelligence level is high, boundary employees may be able to design these interfaces and then let them run these tasks independently. Alternatively, boundary employees need to complement their shortcomings when these technologies are not intelligent enough. Even when these technologies are able to perform the tasks independently for their customers, solution providers need to consider whether the customers have skills and abilities to use them independently; otherwise, they need to offer some support to their customers. On the other hand, for interfaces with low intelligence levels, which focus on information sharing such as EDIs and online communication tools, boundary employees need to understand what skills are needed to use these tools efficiently.

Clearly, digitalization has further transformed boundary spanners' functions, since their traditional solution business functions of leveraging offerings and consultation have been replaced by interface functions such as automatic module reconfiguration and optimization. In this context, boundary spanners such as technical consultants need to perform highly strategic functions to (help) design and manage these intelligent interfaces. This requires knowledge and skills in data analytics and programming – or at least enough fluency with analytics to advise professional programmers – but also retaining an awareness of solution processes and requirements. It is, therefore, likely that future boundary spanners in B2B firms require a very different skillset to assume these responsibilities or that managers need to offer relevant training to their employees to upgrade their workforces. Simply put: it is a fallacy to assume that digital interfaces can just be added to traditional boundary resources without interaction effects. Additionally, while digital interfaces such as chatbots and algorithms can interact with customers independently, solution providers also need to manage the risks in this process. They need to design a system that can flag any arising risks to boundary spanners. They also need to develop smooth transition processes from digital interfaces to boundary spanners when digital interfaces cannot handle customer requests independently. Thus, it is vital that managers rethink their boundary resources as an integral system consisting of heterogeneous but potentially mutually complementing parts that work together to the benefit of the customer, module provider partners and ultimately the firm itself.

8. Future research

As with all qualitative research, our comparative case study findings rely on future research to test their broader applicability in different study contexts, both geographic and industry-specific. We would also encourage such research to distinguish further between different types of boundary interfaces and boundary spanners. This would add granularity to our framework of boundary interactions in different solution phases. For example, algorithms, chatbots and online communities may play different specific roles in boundary interactions. In different contexts, such as B2B services, customer solutions and supply chain management, the same type of boundary interfaces may also assume different roles and have different limitations, which future research should investigate.

Second, since our research emphasizes solution providers' perspectives, our study only focuses on the boundary spanners in the focal firms. Future studies can explore in more detail how boundary spanners can facilitate cooperation among customers, solution providers and module providers. This includes considering the perspective of complementors or module providers; since they are connected by a common digital platform, their boundary spanners' roles may also be influenced by this common platform. Specifically, the platform architecture may have impacts on all actors' respective roles; for instance, the diversity of modules on the platform and the module reconfiguration process may significantly influence boundary interactions. Therefore, future research needs to be attentive to specific platform designs and investigate how these factors influence the roles of boundary spanners in module providers.

Finally and perhaps most importantly, due to the rapid development of AI, we expect digital interfaces to become more and more intelligent and we call on future research to explore cutting-edge technologies as they are being deployed in a B2B boundary context. As AI such as chatbots still have limitations in showing empathy, the "human touch" likely remains irreplaceable in customer relationships – at least for now, but this may change rapidly with the development and spread of more sophisticated virtual realities in B2B. Future research may explore how boundary spanners complement interfaces by managing the emotional dimensions of B2B relationships, such as empathy, mutual trust and conflicts, or alternatively, how these dimensions may be designed into highly intelligent boundary interactions. Importantly, this research needs to be accompanied by ethical and practical considerations on the limitations of AI technologies in inter-firm relationships.

References

Aldrich, H. and Herker, D. (1977), "Boundary spanning roles and organization structure", *The Academy of Management Review*, Vol. 2 No. 2, pp. 217-230.

Barrett, M., Oborn, E., Orlikowski, W.J. and Yates, J. (2012), "Reconfiguring boundary relations: robotic innovations in pharmacy work", *Organization Science*, Vol. 23 No. 5, pp. 1448-1466.

Biggemann, S., Kowalkowski, C., Maley, J. and Brege, S. (2013), "Development and implementation of customer solutions: a study of process dynamics and market shaping", *Industrial Marketing Management*, Vol. 42 No. 7, pp. 1083-1092.

Chakkol, M., Karatzas, A., Johnson, M. and Godsell, J. (2018), "Building bridges: boundary spanners in servitized supply chains", *International Journal of Operations and Production Management*, Vol. 38 No. 2, pp. 579-604.

Choi, T.Y. and Krause, D. (2006), "The supply base and its complexity: implications for transaction costs, risks, responsiveness and innovation", *Journal of Operations Management*, Vol. 24 No. 5, pp. 637-652.

Creswell, J.W. and Miller, D.L. (2000), "Determining validity in qualitative inquiry", *Theory into Practice*, Vol. 39 No. 3, pp. 124-130.

Davenport, T., Guha, A., Grewal, D. and Bressgott, T. (2020), "How artificial intelligence will change the future of marketing", *Journal of the Academy of Marketing Science*, Vol. 48 No. 1, pp. 24-42.

Davies, A., Brady, T. and Hobday, M. (2007), "Organizing for solutions: systems sellers vs systems integrator", *Industrial Marketing Management*, Vol. 36 No. 2, pp. 183-193.

Drummond, C., O'toole, T. and Mcgrath, H. (2020), "Digital engagement strategies and tactics in social media marketing", *European Journal of Marketing*, Vol. 54 No. 6, pp. 1247-1280.

Eisenhardt, K. (1989), "Building theories from case study research", *The Academy of Management Review*, Vol. 14 No. 4, pp. 532-550.

Eloranta, V. and Turunen, T. (2016), "Platforms in service-driven manufacturing: leveraging complexity by connecting, sharing and integrating", *Industrial Marketing Management*, Vol. 55, pp. 178-186.

Evanschitzky, H., Wangenheim, F.V. and Woisetschläger, D.M. (2011), "Service and solution innovation: overview and research agenda", *Industrial Marketing Management*, Vol. 40 No. 5, pp. 657-660.

Frankenberger, K., Weiblen, T. and Gassmann, O. (2013), "Network configuration, customer centricity and performance of open business models: a solution provider perspective", *Industrial Marketing Management*, Vol. 42 No. 5, pp. 671-682.

Friedman, R.A. and Podolny, J. (1992), "Differentiation of boundary spanning roles: labor negotiations and implications for role conflict", *Administrative Science Quarterly*, Vol. 37 No. 1, pp. 28-47.

Gebauer, H., Paiola, M. and Saccani, N. (2013), "Characterizing service networks for moving from products to solutions", *Industrial Marketing Management*, Vol. 42 No. 1, pp. 31-46.

Geiger, S. and Finch, J. (2009), "Industrial salespeople as market actors", *Industrial Marketing Management*, Vol. 38 No. 6, pp. 608-617.

Gibbert, M. and Ruigrok, W. (2010), "The 'what' and 'how' of case study rigor: three strategies based on published work", *Organizational Research Methods*, Vol. 13 No. 4, pp. 710-737.

Glikson, E. and Woolley, A.W. (2020), "Human trust in artificial intelligence: review of empirical research", *Academy of Management Annals*, Vol. 14 No. 2, pp. 627-660.

Gupta, A., Li, H. and Sharda, R. (2013), "Should I send this message? Understanding the impact of interruptions, social hierarchy and perceived task complexity on user performance and perceived workload", *Decision Support Systems*, Vol. 55 No. 1, pp. 135-145.

Hancock, P.A., Billings, D.R., Schaefer, K.E., Chen, J.Y.C., De Visser, E.J. and Parasuraman, R. (2011), "A meta-analysis of factors affecting trust in human-robot interaction", *Human Factors: The Journal of the Human Factors and Ergonomics Society*, Vol. 53 No. 5, pp. 517-527.

Herhausen, D., Miočević, D., Morgan, R.E. and Kleijnen, M.H. (2020), "The digital marketing capabilities gap", *Industrial Marketing Management*, Vol. 90, pp. 276-290.

Hofacker, C., Golgeci, I., Pillai, K.G. and Gligor, D.M. (2020), "Digital marketing and business-to-business relationships: a close look at the interface and a roadmap for the future", *European Journal of Marketing*, Vol. 54 No. 6, pp. 1161-1179.

Jaakkola, E. and Hakanen, T. (2013), "Value co-creation in solution networks", *Industrial Marketing Management*, Vol. 42 No. 1, pp. 47-58.

Jonsson, K., Holmström, J. and Lyytinen, K. (2009), "Turn to the material: remote diagnostics systems and new forms of boundary-spanning", *Information and Organization*, Vol. 19 No. 4, pp. 233-252.

Kaplan, A. and Haenlein, M. (2019), "Siri, Siri, in my hand: Who's the fairest in the land? On the interpretations, illustrations and implications of artificial intelligence", *Business Horizons*, Vol. 62 No. 1, pp. 15-25.

Kindström, D. and Kowalkowski, C. (2009), "Development of industrial service offerings: a process framework", *Journal of Service Management*, Vol. 20 No. 2, pp. 156-172.

Kindström, D. and Kowalkowski, C. (2014), "Service innovation in product-centric firms: a multidimensional business model perspective", *Journal of Business and Industrial Marketing*, Vol. 29 No. 2, pp. 96-111.

Koponen, P.J. and Rytsy, S. (2020), "Social presence and e-commerce B2B chat functions", *European Journal of Marketing*, Vol. 54 No. 6, pp. 1205-1224.

Krafft, M., Sajtos, L. and Haenlein, M. (2020), "Challenges and opportunities for marketing scholars in times of the fourth industrial revolution", *Journal of Interactive Marketing*, Vol. 51, pp. 1-8.

Kragh, H. and Andersen, P.H. (2009), "Picture this: managed change and resistance in business network settings", *Industrial Marketing Management*, Vol. 38 No. 6, pp. 641-653.

Kumar, A., Shankar, R. and Aljohani, N.R. (2020), "A big data driven framework for demand-driven forecasting with effects of marketing-mix variables", *Industrial Marketing Management*, Vol. 90, pp. 493-507.

Lindgreen, A. (2008), *Managing Market Relationships: Methodological and Empirical Insights*, Gower Publishing, Aldershot.

Luo, X., Tong, S., Fang, Z. and Qu, Z. (2019), "Frontiers: Machines vs humans: the impact of artificial intelligence chatbot disclosure on customer purchases", *Marketing Science*, Vol. 38 No. 6, pp. 937-947.

Mason, K., Oshri, I. and Leek, S. (2012), "Shared learning in supply networks: evidence from an emerging market supply network", *European Journal of Marketing*, Vol. 46 Nos 11/12, pp. 1743-1762.

Mero, J., Tarkiainen, A. and Tobon, J. (2020), "Effectual and causal reasoning in the adoption of marketing automation", *Industrial Marketing Management*, Vol. 86, pp. 212-222.

Meuter, M.L., Bitner, M.J., Ostrom, A.L. and Brown, S.W. (2005), "Choosing among alternative service delivery modes: an investigation of customer trial of self-service technologies", *Journal of Marketing*, Vol. 69 No. 2, pp. 61-83.

Miles, M. and Huberman, A. (1994), *Qualitative Data Analysis (2nd ed.)*, Sage Publications, Thousand Oaks, CA.

Nordin, F. and Kowalkowski, C. (2010), "Solutions offerings: a critical review and reconceptualization", *Journal of Service Management*, Vol. 21 No. 4, pp. 441-459.

Patton, M.Q. (1990), *Qualitative Evaluation and Research Methods*, 2nd ed., Sage Publications, Thousand Oaks, CA.

Pawar, K.S., Beltagui, A. and &Riedel, J.C. (2009), "The PSO triangle: designing product, service and organisation to create value", *International Journal of Operations and Production Management*, Vol. 29 No. 5, pp. 468-493.

Perks, H., Kowalkowski, C., Witell, L. and Gustafsson, A. (2017), "Network orchestration for value platform development", *Industrial Marketing Management*, Vol. 67, pp. 106-121.

Perrone, V., Zaheer, A. and McEvily, B. (2003), "Free to be trusted? Organizational constraints on trust in boundary spanners", *Organization Science*, Vol. 14 No. 4, pp. 422-439.

Piercy, N.F. (2009), "Strategic relationships between boundary-spanning functions: aligning customer relationship management with supplier relationship management", *Industrial Marketing Management*, Vol. 38 No. 8, pp. 857-864.

Powers, T.L., Sheng, S. and Li, J.J. (2016), "Provider and relational determinants of customer solution performance", *Industrial Marketing Management*, Vol. 56, pp. 14-23.

Prior, D.D. (2013), "Supplier representative activities and customer perceived value in complex industrial solutions", *Industrial Marketing Management*, Vol. 42 No. 8, pp. 1192-1201.

Prior, D.D. (2016), "Boundary spanning and customer service styles in business solutions implementation", *Industrial Marketing Management*, Vol. 56, pp. 120-129.

Raja, J.Z. and Frandsen, T. (2017), "Exploring servitization in China: challenges of aligning motivation, opportunity and ability in coordinating an external service partner network", *International Journal of Operations and Production Management*, Vol. 37 No. 11, pp. 1654-1682.

Richter, A.W., West, M.A., van Dick, R. and Dawson, J.F. (2006), "Boundary spanners' identification, intergroup contact and effective intergroup relations", *Academy of Management Journal*, Vol. 49 No. 6, pp. 1252-1269.

Roehrich, J. and Lewis, M. (2014), "Procuring complex performance: implications for exchange governance complexity", *International Journal of Operations and Production Management*, Vol. 34 No. 2, pp. 221-241.

Salonen, A. and Jaakkola, E. (2015), "Firm boundary decisions in solution business: examining internal vs external resource integration", *Industrial Marketing Management*, Vol. 51, pp. 171-183.

Salonen, A., Rajala, R. and Virtanen, A. (2018), "Leveraging the benefits of modularity in the provision of integrated solutions: a strategic learning perspective", *Industrial Marketing Management*, Vol. 68, pp. 13-24.

Sawhney, M.S. (1998), "Leveraged high-variety strategies: from portfolio thinking to platform thinking", *Journal of the Academy of Marketing Science*, Vol. 26 No. 1, pp. 54-61.

Steward, M.D., Narus, J.A., Roehm, M.L. and Ritz, W. (2019), "From transactions to journeys and beyond: the evolution of B2B buying process modeling", *Industrial Marketing Management*, Vol. 83, pp. 288-300.

Stock, R.M. (2006), "Interorganizational teams as boundary spanners between supplier and customer companies", *Journal of the Academy of Marketing Science*, Vol. 34 No. 4, pp. 588-599.

Storbacka, K. (2011), "A solution business model: capabilities and management practices for integrated solutions", *Industrial Marketing Management*, Vol. 40 No. 5, pp. 699-711.

Syam, N. and Sharma, A. (2018), "Waiting for a sales renaissance in the fourth industrial revolution: machine learning and artificial intelligence in sales research and practice", *Industrial Marketing Management*, Vol. 69, pp. 135-146.

Tuli, K.R., Kohli, A.K. and Bharadwaj, S.G. (2007), "Rethinking customer solutions: from product bundles to relational processes", *Journal of Marketing*, Vol. 71 No. 3, pp. 1-17.

Wang, Y., Hsiao, S.H., Yang, Z. and Hajli, N. (2016), "The impact of sellers' social influence on the co-creation of innovation with customers and brand awareness in online communities", *Industrial Marketing Management*, Vol. 54, pp. 56-70.

Wei, R., Geiger, S. and Vize, R. (2019), "A platform approach in solution business: how platform openness can be used to control solution networks", *Industrial Marketing Management*, Vol. 83, pp. 251-265.

Yin, R. (2003), *Case Study Research: Design and Methods*, Sage, Thousand Oaks, CA.

Zhang, C., Viswanathan, S. and Henke, J.W. Jr (2011), "The boundary spanning capabilities of purchasing agents in buyer – supplier trust development", *Journal of Operations Management*, Vol. 29 No. 4, pp. 318-328.

Appendix 1. Interview protocol for executives, managers and customers

Executives

- What type of solution does your company offer?
- Please briefly describe the solution process.
- Please describe various module types in the solutions provided by your platform.
- What providers are involved in these modules?

- Please describe how customers and module providers interact on your platforms
- How did your firm design the platform to manage the interactions between customers and module providers?
- Did your firm use different instruments, tools and mechanisms to manage interactions? If so, why?
- How did your firm use software, hardware and employees to manage the interactions? Why?

Managers

- 1. Could you please tell me the role of your function in the overall solution process?
- 2. What problems does it solve for a customer?
- 3. Please briefly describe the process in your function.
- 4. How did your firm use software, hardware and employees to manage interactions in your function? Why?

Customers

- 1. Could you please briefly describe the solution process?
- 2. How did the solution provider use software, hardware and employees to manage the interactions for you?

Appendix 2

Theoretical background	Topics	Deductive codes	Inductive code
Interfaces (Storbacka, 2011; Jaakkola and Hakanen, 2013; Salonen *et al.*, 2018)	Data gathering and synthesis		Gathering data from competitor websites Synthesizing data
	Automatic module reconfiguration		Ranking module providers Matching customer requests with product modules through algorithms Identifying the most suitable service module providers through algorithms
	Network communication	Standardized means to exchange information	Availabilities update
		Information sharing about the same solution	Process monitoring
	Knowledge sharing		Webinars to share technical knowledge about new modules Online forums to share customer experience and usage reports Q&A sections to answer inquiries
	Optimization		Recommending better modules for switching Applying a chatbot to offer guidance and solve administrative issues Sharing data to optimize solution design
Boundary spanners (Aldrich and Herker, 1977; Zhang *et al.*, 2011; Prior, 2013; Chakkol *et al.*, 2018)	Resource mobilization		Integrating orders Dividing an order into small orders Switching orders among providers
	Consultation	Helping customers identify needs and problems	Offering guidance on selecting special modules Representing module providers to recommend modules
	Strategic planning		Gathering data to identify new modules Contacting new module providers to seek collaborative opportunities

(*continued*)

Table A1.
Coding structure

Theoretical background	Topics	Deductive codes	Inductive code
	Community building		Examining module provider capabilities Designing module reconfiguration algorithms Creating topics to facilitate interactions and knowledge sharing Organizing and coordinating online activities with external partners Building trust in online community

Table A1.

About the authors

Dr Ruiqi Wei is an Assistant Professor of Marketing at EMLYON Business School, France. His research focuses on B2B marketing in a digital platform context. Ruiqi's research has been published in *Industrial Marketing Management* and has also been presented at international marketing conferences such as Academy of Marketing Science Annual Conference, American Marketing Association Winter Conference and Industrial Marketing and Purchasing Conference. Ruiqi Wei is the corresponding author and can be contacted at: wei@em-lyon.com

Dr Roisin Vize is a Lecturer in Digital Marketing at Technological University Dublin, Ireland. Her research interests revolve around web retail services and innovation adoption, online B2B relationships including B2B networks. Her research has been published in *Industrial Marketing Management and* has also been presented at international marketing conferences.

Dr Susi Geiger is a Professor of Marketing and Market Studies at the College of Business, University College Dublin, Ireland. Her research focuses on how complex markets are organized and B2B marketing, with specific interests in technology and health-care markets. She has published on these issues, for instance, in *Organization Studies*, *Research Policy*, *Entrepreneurship Theory and Practice*, *European Journal of Marketing*, *Marketing Theory, Journal of Business Research* and *Industrial Marketing Management*.