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Supply Chain as a Service: Building Supply Chain Capability as a Business Model

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Abstract

With the trends towards servitization and digital innovations in supply chains (SCs), a number of SC leaders have started to commercialize their SC capabilities as services provided to business customers. In order to efficiently organize multiple suppliers' resources and customize the service offerings, some of these leaders have developed a "supply chain as a service" model (hereafter SCaaS), in which different functions of a SC, are grouped into service modules to enable plug-and-play agility in meeting the varying needs of business customers. Although SCaaS is emerging as an evolution of the market for cloud services (as with other "X as a service" models like Software as a Service, Platform as a Service, and Infrastructure as a Service), supply chain management (SCM) researchers have not systematically studied the SCaaS phenomenon, which has evolved from a cloud computing application to a new business model at the ecosystem level.

This study explores how a SCaaS has emerged and how it works by instigating three complementary research questions: (1) how do a firm form its SCaaS through the interactive implementation of supply chain innovations (SCIs) and business model innovations (BMIs) over time; (2) what are the roles and activities that SCaaS incorporate, and how these roles and activities are organized to serve the business customers; and (3) what is the detailed service operation process of SCaaS for satisfying a specific customer demand. To address these questions, this study adopts a longitudinal case study approach to investigate a SCaaS formed by Haier COSMO, a company which connects together customized orders, third-party R&D solution providers, intelligent manufacturing factories, and other SC service providers, to provide mass customized SC services to business customers.

This study makes contributions to both the SCM and the service innovation literature. It expands our knowledge of SCI-driven BMIs and echoes with recent calls to refocus SCM on the perspectives of value co-creation and service ecosystem. The study also reveals new insights into how to apply digital technologies to enhance SC capabilities, and how to apply these SC capabilities to support new business models. The findings provide important managerial insights for firms to design and implement new business models in today's trends towards open innovation and value co-creation with ecosystem participants.

Keywords: "supply chain as a service" model (SCaaS), supply chain innovations (SCIs), business model innovations (BMIs), service modularity, longitudinal case study

1. Introduction

For many firms, the value proposition has shifted from purely providing a product or service to the provision of a product-service system (PSS). This often involves diverse third-party providers of complementary services/products throughout the system's life cycle (Brax and Visintin, 2017; Yang *et al.*, 2018). Firms are putting efforts into the innovation of the design and management of their SCs to support such complex PSS (Resta *et al.*, 2017). We have observed a trend for the focal firms to provide SC solutions to the independent complementors of their PSSs. With the help of digital technologies and through the cloudification and modularization of their SC capabilities, some focal firms have even developed a SCaaS. Through such a model, firms can provide commercial mass customized SC solutions to their SC members or even non-SC stakeholders (external firms).

For instance, in addition to its core PSS business, Haier, a giant in home electrical appliance industry, has also developed a SCaaS to provide mass customized SC solutions to external firms, which is the subject of this case study. Meanwhile, in China's retail industry, JD.com, known as China's Amazon for its advanced SC and logistics, has also modularized its SC capability, offering services to enable external brand companies, omni-channel distributors, and even offline retail stores to help them better cope with the individualized, fast-changing customer needs. According to Gartner, SCaaS is also considered as an "on the rise" supply chain strategy in "hype cycle of supply chain strategy 2018" (Tohamy, 2018).

Nevertheless, surprisingly little theoretical work has been done on SCaaS. Although the concept was first introduced in 2011 from the cloud and engineering perspective, and has generally been considered to be similar to other "X as a service" models (Leukel *et al.*, 2011), follow-up studies are rare. Furthermore, according to recent business practices and some of the SCaaS phenomena we have observed, we found that the cloud and engineering perspective cannot summarize or reflect all the characteristics of SCaaS. The emergence of SCaaS has been accompanied by a change in firms' business paradigms and dominant logic (Resta *et al.*, 2017). However, the characteristics of SCaaS in terms of BMI and service-dominant logic (S-D logic) have not been captured. We know little about how to build a SCaaS business model, rather than providing cloud-based SC services, or through what mechanisms a SCaaS can enable value co-creation activities among suppliers and customers and other related parties. Answers to these questions may lead to new insights into how SC capabilities facilitate co-creation of value in a business ecosystem characterized by loosely coupled actors. This is particularly important for firms in today's trend toward open innovation, business ecosystems, and co-creating value with external entities (Altman and Tushman, 2017).

Based on these gaps in the literature, the purpose of this study is to explore how a SCaaS has emerged and how it works under the S-D logic perspective. Through this process, this study aims to provide a comprehensive understanding of SCaaS, in the context of manufacturers' servitization. To do so, this paper presents a longitudinal case study, of the home appliance giant Haier, investigating in-depth how it transformed its

SC capability into SCaaS. This study contributes to the research on SCM and service innovation by applying S-D logic-based thinking to identify SCaaS, and by revealing the detailed emerging and operational mechanisms (in particular, the value co-creation activities among multiple interaction processes) underpinning SCaaS.

The remainder of this paper proceeds as follows. Section 2 includes the literature review. In Section 3, the in-depth case study methodology is presented. In Sections 4, research findings are described. In Sections 5 and 6, propositions are developed and findings and implications are discussed.

2. Theoretical background and research questions

2.1 The positioning of SCaaS

PSS is defined as a transformed model of traditional product-based business towards increased strategic and operational service emphasis (Resta *et al.*, 2017; Brax and Visintin, 2017). It provides service portfolio of "integrating and customizing common subsystems, modules and components of hardware, software and service" (Brax and Visintin, 2017, p.22), which are jointly produced and operated with loosely coupled third parties. Therefore, first, compared to traditional manufacturing SCs which mainly include functions of R&D, procurement, production, distribution, consumption and disposal, and follow a linear "take, make and dispose" process (Yang *et al.*, 2018), the SC of PSS incorporates more functions, such as richer customer services, installed software operation, and recycling, covering the entire life cycle of a product-service solution (Holmström *et al.*, 2010), by an end-to-end close-looped manner (Yang *et al.*, 2018). As pointed out by Lusch (2011) "SCM is moving into a 'super' role." (p. 14). Second, different from traditional manufacturing SC which is characterized by highly structured and rigid ties between suppliers, customers, and other SC partners (Jiao *et al*., 2007; Sköld and Karlsson, 2013), the SC of PSS forms a SC network of primarily weak ties among SC members.

Scholars argue that SC (re)design should be considered an important step in developing PSS (e.g., Brax and Visintin, 2017). Resta *et al*. (2017) reveal that the relationships between SC partners have changed from vertical (multiple-layer) to horizontal (with third parties loosely coupled in the network). Rajala *et al*. (2019) find that as product-oriented integrated solutions move toward modular solutions, the functions of the SC should be modularized, and third-party complementors providing modular add-ins should be involved in every function of the SC. These studies require the design and management of the PSS SC to focus more on accessing and coordinating various complementors of each SC function throughout the whole life cycle of a product-service solution (Brax and Visintin, 2017), guided by the S-D logic (Resta *et al*., 2017; Vargo and Lusch, 2004a, 2004b, 2008). The S-D logic views SCs as value co-creation networks and emphasizes value co-creation activities among SC members (Lusch *et al.*, 2010; Tokman and Beitelspacher, 2011; Flint *et al.*, 2014). This view helps the focal firm of a PSS to use value co-creation as the basis for better SC coordination.

SCaaS has been developed based on PSS SC. Scholars reveal that the PSS provider holds the focal position in the service ecosystem “which can be intended as a set of nested SCs, acting as integrator of external resources” (Resta *et al*., 2017. p.308). Therefore, the focal firm needs not only to coordinate autonomous entities with different goals to jointly serve the PSS (Leukel *et al*., 2011), but also to manage a series of nested SCs. It needs to ensure the supply capacity and efficiency of these autonomous entities. For instance, if a third-party complementor has a problem in its R&D, procurement, production, distribution, or other SC functions, the PSS will probably be required to efficiently provide solutions through other internal and external SC resources. SCaaS is developed in such situations. It is a reorganization of the original PSS SC resources and members into new demand-supply relationships in a new value proposition scenario of the commercial SC service.

Table 1 compares the evolution of concepts related to SCs. These studies help us understand the research profile related to SCaaS and locate the research gaps.

--------------- insert Table 1 about here ----------------

2.2 SCIs and BMIs in generating SCaaS

Although SCI has been widely analysed in operations and SCM literature, most of the existing studies have considered SCI as complementary or supportive activities to a final product/service or a business model. The emergence of SCaaS gives us an opportunity to view SCI and BMI in a unified perspective and explore how they affect each other.

Traditionally, BMI and SCI do not have the same level of abstraction: the former has a higher level of abstraction (in that it applies to the strategic level) than the latter (which works at the operational level) (Abdelkafi and Pero, 2018). However, best practices in SCI increasingly illustrate BMIs. For instance, Dell's virtual SC is also referred to as an innovative direct sales business model (Simchi-Levi *et al.*, 2003; Magretta, 1998). Amazon's agile SC is also presented as the "Amazon effect" – a new benchmark for e-commerce business models (Johnson, 2010; Melnyk and Stanton, 2017).

As SCs are changing from tactical to strategic (Melnyk, 2016) and their focus is shifting from intra-function to cross-function integration (Lusch, 2011), the role SCI can play in business transformation is also changing and becoming dominant (MacCarthy *et al*., 2016). The relationship between SCI and BMI is also changing. Very few attempts have been made to connect the BMI and SCM streams of research. Munksgaard *et al*. (2014) conducted the first study on how SCI contributes to BMI from a value-based perspective (Abdelkafi *et al*., 2013); that is, they focused on value creation, value delivery, and value capture. Abdelkafi and Pero (2018) created a bridge between SCIs and BMIs and identified SCI-driven BMs "where a SCI has a major impact on the core activities of the company and is fundamental in shaping at least one of the five value elements (value proposition, value capture, value creation, value delivery, and value communication) of the BM" (p. 601). These studies reveal that BMIs can be a part of SCIs; conversely, an SCI can be also a part, or even the whole, of a BMI. SCI acts on core activities; it has the potential to change the BM, which is understood as a system of core activities (incremental BMI), or to enable the generation of a new BM (radical BMI) (Abdelkafi and Pero, 2018).

2.3 Value co-creation in SCaaS

S-D logic views actors in a SC network as "making value propositions to each other versus delivering or adding value……. and hence has a strong focus on collaborative processes". (Lusch, 2011, P. 15). S-D logic provides a generalized and macro view of the interactions among loosely coupled actors to co-create value through operand and operant resources (Lusch, 2011; Vargo and Akaka 2012). However, there is still a lack of knowledge of how the mechanism operates, how the detailed value co-creation activities take place among multiple interaction processes, and how to achieve the systemic and synergistic effects of the value co-creation network (Lusch *et al.*, 2010; Lusch, 2011). Although the engineering design perspective focuses on the detailed day-to-day operation, this view has not expanded its scope of application from strongly linked SC netwroks to weakly linked SC networks.

In a recent study, Jacobides *et al*. (2018) proposed two types of value co-creation modes in service ecosystems: one with unique complementarities, defined as a mode in which "A doesn't 'function' without B" (i.e., the idea of co-specialization); and one with a supermodular complementarity, defined as a mode in which "more of A makes B more valuable". This study provides insight for us to analyze the value co-creation mechanism in the SCaaS in terms of the conditions under which or in what ways external participants in the SCaaS can offer unique or/and supermodular complementarities with the focal firms. To some extent, a SCaaS is an open service system that helps the PSS provider to motivate and manage the third-party complementors. How a SCaaS synergistically works with the PSS to facilitate value co-creation and how the two kinds of complementarities are implemented need to be explored in an empirical analysis.

2.4 Literature summary and research questions

In summary, research gaps in relation to the SCaaS mainly concern three areas. First, the characteristic features of the SCaaS and how it works have not been well investigated in previous studies. Second, SCaaS is an up-to-date SCI-related concept. It is also at the intersection of SCIs and BMIs. Theoretical work needs to be done to explore how firms build SCaaS through the interactive implementation of both SCIs and BMIs. Third, according to Leukel *et al*. (2011), the SCaaS has mainly been implemented as a kind of cloud service. Through the idea of modularity and the concept of resource pool, the SC resources can be decomposed into standardized modules that can be reconfigured (adding, removing, or modifying) with scalability, depending on customer demands. In a broad sense, Leukel *et al*. (2011) explains how a SCaaS works like a cloud service, but the specific value co-creation mechanism among SC members and the detailed service process based on the modularity and the resource pool are not clarified.

Based on these research motivations, this study explores the following three related research questions

RQ1: How do a firm form its SCaaS through the interactive implementation of SCIs and BMIs over time?

RQ2: What are the roles and activities that SCaaS incorporate? How these roles and activities are organized to serve the business customers?

RQ3: What is the detailed service operation process of SCaaS for satisfying a specific customer demand?

3. Methodology

3.1 Case study design

Since we are examining a relatively new phenomenon with limited explanatory works done (Suddaby, 2006; Gligor and Autry, 2012), a case study method is appropriate to derive theory from field data (Eisenhardt, 1989; Strauss and Corbin, 1990; Yin, 2009). This approach provides rich insights by observing actual practices in context (Weick, 2007) and allows empirical development of testable theories (Closs *et al*., 2008; Pagell and Wu, 2009). Further, the case study method can qualitatively capture the features of the emergence and evolution path of SCaaS over an extended time horizon (Pathak *et al*., 2007).

Specifically, a longitudinal study on a single company is adopted for the following reasons. First, the formation of SCaaS is a continuous, dynamic, and complex process. Compared to a multi-case study, a single case study can focus better on the research subject, ensure the depth of the case analysis, and fully explore the key points and details in the case data (Eisenhardt, 1989). Second, this study focuses on the uniqueness of a single case and its implications. The unique single case is more helpful in generating theoretical insights, and can inspire innovation in other enterprises (Siggelkow, 2007).

3.2 Case selection and description

We chose mainland China as the research setting as China has evolved into a world's manufacturing center and consequently its SCs cover a wide range of industries, with a great many of industry clusters where large numbers of factories, brands, distributors and supportive service providers co-exist.

In view of the uniqueness of case selection and the availability of data (Eisenhardt, 1989), we selected Haier as the sample firm. As the world's largest appliance maker and a symbol of "Made in China," Haier has always conscientiously exerted itself to cope with industrial and technological change. Over the last 36 years, it has evolved from a mass production manufacturer (1984–2008), to a mass customization manufacturer (2008–2014), to a smart-home PSS provider (2014–present). With an annual revenue of RMB 183 billion in 2018, it is competing with world-class household brand companies such as Whirlpool, LG, and Electrolux (Hamel and Zanini, 2018).

In addition to its core appliance business, since 2016, Haier has been working on developing a set of B2B SC solutions with an independent brand "COSMO", which has self-governing intellectual property rights. COSMO now provides a comprehensive set of SC solutions across 15 industries, including ceramics, mobile homes, and clothing, empowering enterprises in these industries to transform and upgrade their businesses. The revenue of COSMO during the first three quarters of 2019 was RMB 8.06 billion (around 5% of Haier's total revenue), with a year-on-year increase of 55% (Report of 2019Q3, Haier smart home, 600690[1]). The IEEE, ISO, and IEC, three major

[1] http://www.haier.net/en/investor_relations/haier/

international standards-developing bodies, have chosen Haier to lead the development of international standards for the model of mass customization and industrial Internet platforms (Report of 2018Q3, Haier smart home, stock code: 600690[2]).

3.3 Data collection

This study combined multiple data-collection methods. The primary method was in-depth interviews with key members the sample firm's staff over almost six years (2014–2019). These semi-structured interviews followed a protocol (see Appendix). The interviewees were asked about SC strategies, SCIs, BMIs, and servitization. Their experiences were explored from a longitudinal perspective; they were allowed a great deal of freedom to express their views and raise new issues (Yin, 2009) to explore the naturally occurring data (Silverman, 2006). Researchers of this study were careful not to use terminology such as "service modularity" and "SC ecosystems" so as not to prompt the interviewees. Interviewees were selected from different business units and organizational levels in order to increase the reliability and internal validity of the data generated in the case study (Yin, 2009). To explore the role of COSMO, the research team also conducted three pairs of dyadic interviews with members from both the Haier COSMO SC service project team side and from the empowered business customers' side. Table 2 provides a summary of the interview data.

---------------- Insert Table 2 about here ----------------

Additional data were collected by the authors' participating in and observing joint or

[2] http://www.haier.net/en/investor_relations/haier/

internal workshops and other collaborative activities with the sample firm (see Table 3). Over 2014–2019, the research center that the authors were affiliated with held several industry–research collaborative summits and workshops, on the topics of SCIs, SC servitizations, and transformation in SCs. Different levels of managers of the sample firm were invited to give keynote speeches or to participate in round-table discussions. Much conversation and discussion took place, providing us with valuable insider information on the case company. This was very helpful, as data related to one topic could be gathered at the same time from multiple representatives and diverse actors (Mena *et al*., 2013; Perks *et al*., 2017). In addition, essential secondary materials such as third-party reports were also collected. The use of diverse data sources enabled verification and triangulation of the results (Eisenhardt, 1989; Yin, 2009). Overall, the major empirical data comprised a total of 45 in-depth interviews with 30 interviewees and observation of 10 workshops or meetings.

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3.4 Data analysis

The coding process is adapted from Gioia *et al*. (2013)'s methodology, which is inductive and allows researchers to iterate between data and theory.

We attempted to trace and comprehend the sample firm's history in detail, especially its strategic, operational and technological innovations, and contextual factors like environmental change and industrial competition. Then, we focused on SCIs and BMIs, paying particular attention to data relevant to keywords like SC modularization, SC “empowerment”, service modularity, and SC service ecosystems.

The specific coding procedure was undertaken in three steps. First, we started with no predetermined coding, similar to Strauss and Corbin’s (1990) notion of open coding (Gioia *et al*., 2013). One author conducted multiple rounds of comparison and combination of similar or different themes that emerged; these themes were double-checked individually by other authors to ensure their consistency. Where controversial issues arose, the coding process returned to the initial coding. Through this step, we derived a set of first-order concepts.

In the second step, we explored theoretical interpretations of the first-order concepts. This involved an iterative process of comparison and matching between concepts and the extant literature on SCIs, service modularity, and BMIs. We tended to use concepts identified in previous research to summarize the second-order themes, as suggested by Pan *et al*. (2008) and Li *et al*. (2018). We follow Zott and Amit (2010) and use the three design elements of “content (the selection of activities and value propositions), structure (how the activities are linked), and governance (who performs the activities)” to identify BMIs in the data. The classifications of SCI are multiple and varied in the literature. However, most of the classifications are based on the precondition that considering SCI as complementary or supporting activities to a final product/service or a business model. For instance, Bello *et al*. (2004) and Wong and Ngai (2019) divided SCI as logistics-oriented, marketing-oriented and technological development-oriented innovation activities. However, these classifications cannot summarize the innovation characteristics in the servitization process of the SC capability. Therefore, we adopt a service product innovation perspective (Voss and Zomerdijk, 2007) to investigate SCIs in the sample case, focusing on exploring how SC capability is transformed to innovative SC service products. Based on the theoretical similarities and differences among all the first-order concepts, we grouped them and developed the second-order themes.

In the third step, we focused on distilling the second-order themes into aggregate dimensions. Based on a better understanding and clarification of SCIs and BMIs, and their interactions through the practical cases and literature in the second step, ultimately, a SCaaS model emerged as the focal category of our study. Figure 1 shows the data structure.

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4. Case analysis and findings

Two themes emerged from the case analysis. One is how Haier built its end-to-end modular SC capability, and the other is how Haier transformed its SC capability into SC solutions and developed its SCaaS. Therefore, we theorized the formation of Haier's SCaaS into these two stages. In the first stage, Haier built its end-to-end modular SC capability to serve its own PSS. The second stage, Haier went on to transform this new SC capability into SC solutions for external firms and finally to build the SCaaS.

According to the data analysis, the second stage could itself be divided into three steps, in terms of the work Haier did before and after it launched its new B2B SC solution system, COSMO, independent of the original SC system serving its own PSS. This analysis reveals the interactive implementation of SCIs and BMIs at each step and between each step.

Step 1: transforming capabilities in each SC function into commercialized, single-function SC solutions. This step, during 2014-2016, can be considered as a pre-COSMO period, when Haier attempted to provide B2B SC solutions but these were still based on its original SC system. In step 1, Haier mainly provided single-function SC solutions and ran separate platforms for each SC function.

Step 2: transforming capabilities of SC integration into commercialized, cross-function SC integration solutions. This step, during 2016-2018, can be considered an initial version of COSMO. In this step, Haier integrated many of its SC solutions and launched COSMO in the end of 2016, but the SC solutions were mainly be provided by specialized service project teams of COSMO.

Step 3: implementing the SCaaS. This step, from 2018 to the present, can be considered as an advanced version of COSMO. In this step, Haier developed mass customized SC solutions, which balanced service efficiency with the meeting of diverse needs.

The following subsections explain the detailed transitions in Haier's SC services and how it evolves towards SCaaS, as identified in the data analysis. As shown in Figure 2, the main developments at each stage and each step are described by the roles of SCIs, BMIs, and their interactions.

-----------------------------------Insert Figure 2 about here------------------------

4.1 Stage 1. Building its end-to-end modular SC capability to serve its own PSS

SCI stage1-1: Transforming a mass production SC into a mass customization SC

During its long era of mass production (1984-2008), Haier had put a lot of effort into the improvement of its SC capability, in order to produce standardized, good-quality products at low cost. Haier had set up a SCM department and appointed a VP in charge of SCM. The company had also developed a 4T[3] ("Time, Target, Today and Team") mass production SC system to match its production capacity to the market forecast in terms of both time and quantity. Based on its advanced mass production SC capability, during the 1990s the Haier brand had been a symbol of high quality.

Later, with the diversification of customer needs and product categories, Haier found that the mass production SC capability could no longer deliver the advantage of cost reduction. This was largely because the diversification of product models had resulted in an increase in the number of different components and parts. Purchasing many more types of accessories also multiplied the complexity and coordination of procurement and inventory management, which finally led to an increase in costs (Zhao and Wang, 2016). Therefore, after 2008, Haier changed its mass manufacturing SC into a mass customization SC by the following two processes.

First, Haier adopted modular thinking (modular design, modular procurement and

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[3] In terms of "Time" and "Target", Haier matched its production line to the market forecast by breaking down the forecast production capacity into daily workloads, work instructions, and schedules for hundreds of specific steps and procedures in the production line. Also, by exerting billboard management, the transparency and visualization of the production process were further enhanced. The completion of a T-1 procedure would trigger the initiation of T+1 procedure immediately, increasing production accuracy and speed. In terms of "Today" and "Team", Haier created the unique OEC (Overall Every Control and Clear) approach to train the team. All employees had their own target to meet. At the end of each day, there would be a cross-check between today's target and the actual result. Employees could draw experience from each day's work and put a timely stop to shortfalls (Zhao and Wang, 2016).

modular production) and decomposed the old, rigid SC system into relatively independent SC functions. In terms of modular design, Haier forged a whole set of methodologies on product decomposition. Products in all business lines could be re-designed into the configurations of a series of modules. In terms of modular production, Haier developed a SKD (Semi Knock Down) modular production line. Different modules of one product can be prepared in parallel in their own modular lines, and then arrive at the main assembly line for quick assembly. In terms of modular procurement, Haier gradually replaced the former components and parts suppliers with module suppliers. Therefore, since a lot of modules were already provided by module suppliers, procurement uncertainty and inventory costs were reduced.

Second, Haier modularized SC functional resources through a “market chain” logic, changing the traditional administration-based relationship between sequential operations in the SC to an “internal market” (such as buyer-seller) relationship. Thus, external market orders were transformed into a series of internal market orders. Furthermore, Haier modularized its functional management resources to form independent supporting service modules (internal profit centers), such as information management, technical quality administration, equipment management, and legal services.

By the end of 2011, Haier had basically achieved the “3R”s: reliable, rapid, refined production of different models. The diversified customer needs had been well satisfied. Based on the modular SC, Haier established its 1-6-1 weekly order system: lock one week’s order and plans, forecast the demand, prepare the resources needed for the next six weeks, and review the errors in last week's order fulfillment and identify who is responsible for it. With this system, orders were placed weekly, the supply was driven by demand, and the average stock turnover was reduced to 5-7 days. Compared with the traditional inventory in the home appliance industry, typically up to several months, Haier had almost reached "zero inventory" (Zhao and Wang, 2016).

SCI stage1-2: Developing separate platforms for each single SC function to manage resources and jointly provide PSS

As the Internet began to grow in China, the end users of its home appliance products, began to play critical roles in the market. Therefore, like other manufacturing firms transforming into providing services in addition to their products (Rajala *et al*. 2019), Haier started to provide PSS, including individualized order creation, product design interaction, traceability in manufacturing and logistics, the last-mile delivery and installation service at a particular time slot ordered by the customer, and a continuous customer service, via the Internet, on the use of the products.

In order to support such PSS, the mass customization SC capability needed to be enhanced so that it could more exactly meet individual needs. This was done by flexible reconfiguration of end-to-end SC resources. Haier thereby built an advanced mass customization SC capability, a so-called "configuration-to-order" (CTO) capability, through which individualized orders could be decomposed into sub-processes to be fulfilled at different SC functions (procurement, production, logistics, etc.). In addition, information was shared among these SC functions so that the final PSS could be jointly produced.

In developing the CTO capability, Haier found that the traditional linear structure of its SC (with the disadvantage of lacking direct communication between companies upstream from Haier and those downstream) was no longer suitable, as the upstream was always slow to respond to downstream demand changes (all information had to be conveyed via Haier). Therefore, Haier developed separate platforms for each single SC function and changed the logic behind how ideas and resources interacted among different participants.

For instance, in terms of the SC function of customer services, Haier established a smart-home service platform, "Haierplus," which attracted more than 100,000 third-party installation/ maintenance service providers and software developers. In terms of interactive design, Haier developed a users' creative idea collection and interaction design platform. Users can participate in the new product conception process and interact with solution designers. Third-party solution designers can not only get inspiration from user-generated discussions, but also get support from Haier (funding or access to suppliers). As for the SC function of logistics, Haier established a logistics platform, which attracted many third-party delivery drivers and last-mile service providers. Haier also updated the SC function of R&D to be an open technology exchange platform, which supports a variety of formal and informal interactions between external experts, pioneering users, and other stakeholders to solve a wide range of technology challenges, especially cross-industry and cross-field technology applications. Following the same logic, Haier also changed the SC function of procurement to a sourcing platform so that external providers of components can freely compete; this obviates any potential problems with corruption in the procurement process.

Through these separate platforms for each single SC function, Haier has attracted various third-party resources in different SC functions for better PSS provision.

4.2 Stage 2. Transforming SC capability into SC solutions for external firms

Step 1: Transforming capabilities in each SC function into commercialized single-function SC solutions (2014-2016)

BMI-step1-1 (value proposition): Developing a new group of customers (external firms) and providing them with single-function SC solutions.

With the development of these separate platforms for each single SC function, leaders of these platforms realized that, due to the single-source demand (all customer service demands are based on Haier's products, and all product design and R&D demands are from Haier's system), it was difficult to facilitate the engagement and value co-creation activities of third-party complementors. Limited internal demand prevented the platform from reaching its full potential.

One interviewee described the original reason for providing an R&D solution to external firms:

> "*We've also been opening our own (R&D solution) over the past two years, such as inviting large companies in other industries to our platform if they need an R&D solution. If the platform is a market, the two sides need to grow together; if it is only*

for Haier's demand, we may not be able to fully implement our R&D solution. Therefore, we collect demands extensively, and there are more than 200 clear demands on our platform every year; sometimes there are three or five hundred." (Manager, R&D platform)

Therefore, the platforms for the different SC functions redefined their value propositions. The "open platform" was open not only to the supply side (third-party service providers) but also to the demand side (external firms that need single-function SC solutions). In 2014, the logistics service was the first to be commercialized to external brand companies; since then, other SC functions, including R&D, procurement, customer services, and interactive design, have been progressively commercialized (see Figure 3).

BMI-step1-2 (governance mechanism): Changing the relationship with third parties from unique complementarity to supermodular complementarity

The opening of the demand side also changed the relationship between Haier and its third parties. If the third-party suppliers produce specialized parts and components only for Haier, they are unique complementary partners (co-specialization). By opening the demand side, what they provide can be used not only by Haier but also by other external business customers. Therefore, the relationship between Haier and the third-party suppliers changed to supermodular complementary partners, which will effectively stimulate the innovations of third parties.

For instance, one manager of the R&D platform described that, *"There are external experts of the thermal field in our platform, a lot of home appliances products need thermology in their R&D process. When our platform was opened to external business customers, a firm of the tobacco industry came to ask whether we can provide R&D solutions related to heat transfer system for e-cigarettes. We provided them what our external experts provided to us. These experts had been encouraged a lot because their solutions were applied to more areas."* (Manager, R&D platform).

The director of the R&D platform also stated that,

"There are far more examples, our refrigerator preservation technologies were applied to the nutrition loss control of traditional Chinese medicine industry, our air conditioning solutions were applied to the automotive industry for in-car air purification and formaldehyde treatment problems…. the maximum number of times a single solution had been delivered was 80. That was a charging solution which had been delivered to 80 firms in different industries. It was developed by an expert team of fuel cell industry….. Business customers from various industries were attracted by our expertise and strong community of external experts in some of our solutions. The increase of business customers has also facilitated the increase of participation and activeness of the experts and other complementors" (Director, R&D platform).

According to Jacobides *et al*. (2018), supermodularity is the basis of network effects. In the example of an OS platform, Jacobides *et al*. (2018) point out that the app and the OS have a supermodular complementarity in the sense that the presence of apps increases the value of the OS, and the breadth of the installation of the OS increases the value of the app. This can be applied to our case context, the presence of the third-party complementors increases the value of the R&D platform, and the breadth of the adoption of the platform by business customers increases the value of the third-party complementors. This evidence show that, through achieving supermodular complementary, complementor's engagement and value co-creation can be highly improved.

SCI-step1-1: Turning experience into a methodology for developing basic single-function SC solutions

In the first stage, Haier had accumulated much experience in capability development for each SC function. In the second stage, the data shows that the priority was to make the internally held experience in developing these capabilities externally available, and forge a whole set of methodologies in developing basic single-function SC solutions which can be applied within other firms and industries. For instance, based on its experience on supplier management innovation, Haier summarized a methodology of how to help external firms to facilitate their suppliers' transformation from component suppliers into module suppliers, with detailed implementation processes, standards, and incentive mechanisms. Similarly, based on its experiences on user interaction, customer services, and logistics in the home appliances area, Haier also summarized methodologies on how to help external firms to implement interactive design, add services for products, and optimize logistics resources.

SCI-step1-2: Decomposing the basic single-function SC solutions into service modules, and developing more service modules for offering a series of specialized single-function SC solutions

The case data shows that successful production of SC capability relied not only on turning experiences into methodology, but also on interaction with business customers, which can help to decompose and elaborate the basic service categories into a series of service modules.

According to our interviewees, when they started to provide basic single-function SC solution, these solutions were based on their own PSS or servitization transition experience which may work well in some scenarios, but may not work well in others. Based on these basic solutions, each single-function SC platform had provided several project-based solutions for big customers. Through multiple rounds of interactions with these customers on their diversified needs and scenarios, Haier decomposed its basic solution according to customer's complex requirements, and gathered third parties through the platform structure to provide complementary products/services. Sometimes, Haier needs to integrate knowledge from third parties and jointly develop new modules for the customized solutions, or invite third parties to independently develop new service modules. For instance, in order to provide solutions for the R&D activities of Faurecia, one of the world's largest suppliers of automotive engineering solutions and auto parts, Haier jointly developed automobile air-conditioning service modules with third parties in Haier's home appliance R&D platform.

Through carefully defining the third parties' qualification, business customers' requirements and feedbacks, and SC solution offering process, standardized service modules were gradually identified and developed prior to the definition of customers' requirements. The integration work is mainly undertaken by Haier. These modules can also be provided separately or combined with the customer's existing solution. Haier remains in charge of monitoring the whole process, deciding what is to be implemented by Haier and what is to be implemented by the third parties.

Through these processes, increasingly specialized single-function SC solutions were identified by composing a series of service modules according to different scenarios. For instance, as shown in Figure 3, four specialized solutions have been derived from the initial basic procurement solution: mold development solution, group purchasing solution, procurement process optimization, and supplier relationship management.

It is worth mentioning that the elaboration of the specialized service modules and solutions within each SC function also promotes the Haier's original PSS business.

------------------------------------Insert Figure 3 about here-------------------------

Interaction between SCI and BMI in step 1

The case data show that, in step 1, two BMIs have driven two SCIs. (1)The new value proposition (provision of single-function SC solutions to business customers), and (2) the new governance mechanism (updated the relationship with third parties) have jointly lead to the development of basic single-function SC solutions and the decomposition and elaboration of the basic solutions.

Step 2: Transforming capabilities of SC integration into commercialized cross-function SC solutions (2016-2018)

The case data shows that, when their needs within a single SC function are satisfied, external resource providers and customers registered in different single-function SC platforms are likely to cross to other, additional SC functions, to overcome any weaknesses in the single SC function they are presently using, or to generate extra demand. For instance, some business customers in the R&D platform hope that instead of providing technical solutions only, the platform can further help them applying (or deploying) the technical solutions in their production process in an efficient manner. Some customers in the procurement platform hope the platform can provide an integrated sourcing and in-bound logistics service. Furthermore, external complementors also have the need to interact with the parties in other SC functions. For instance, independent designers always seek to meet user needs through innovative product design, but the biggest difficulty for them is that they often do not have sufficient technical information about how a design might be implemented. So the manager of the interactive design platform also wants to help designers connect with the resources available on the R&D platform. Thus, to develop better SC solutions, the linkages among the independent parallel single-function SC platforms should be well established. This view was quickly accepted at the group level, and Haier began to integrate its SC solutions in different single-function SC platforms. It applied its experience of SC integration to SC integration solution business for external firms, and so was able to provide a new value proposition, besides the PSS offered in prior stage.

SCI-step2-1: Turning experiences into a methodology for developing basic cross-function SC solutions

Haier had rich experience in SC integration. Therefore, when it chooses to provide SC integration solutions to external firms, it had forged a whole set of methodologies, such as how to help external firms to transform mass production SC into mass customization SC, how to build the CTO capability, and how to transform product provision into PSS provision.

One Haier top executive described such methodologies when applying its experience of mass customization to help a traditional manufacturer's transformation:

> "*The process is summarized clearly, such that it is easy to implement, as guidance for our business customers to follow. First of all, after the user demand is proposed, the designer will submit some specific design plans by way of bidding. In the process, the data collected in the customer services platform will provide them with inspiration and help them improve their design. Then, the user community votes for the best design. After that, in order to implement the technical plan, the selected design plan is verified by the R&D platform, and the design is further refined. This node will produce a virtual/real product prototype, incorporating product appearance, product function, and product price range. Finally, after verification, we re-test the design by pre-booking. If the consumers really intend to buy it, it will*

prove to be a successful design, and we will pre-sell through our various e-commerce channels and drive the supply and production." (A top executive of Haier)

Haier also developed a series of cross-function modules, especially for the cross-function SC integration solutions (different from the ones for its own PSS), such as underlying technical resources (e.g., cloud server, algorithm libraries, and database), cross-function management information systems (e.g., ERP, OMS, MES, WMS), process integration and real-time process visibility. These cross-function modules help Haier to coordinate various single-function SC solutions.

-----------------------------------Insert Fig 4 about here------------------------

SCI-step2-2: Developing new SC functions and specializing cross-function SC solutions

Since 2012, Haier has been making efforts to speed up product development by applying intelligent manufacturing solutions and building "interconnected factories", which focus on developing a flexible mass customization process by using intelligent technologies. In 2016, Haier set up an intelligent manufacturing research institute to study how to commercialize its intelligent manufacturing solutions to help external firms optimize their production processes. Then, in 2017, Haier commercialized the last key SC function of its SC, namely the marketing solution. In total, Haier has developed seven categories of solutions (customer services, interactive design, R&D, procurement, logistics, intelligent manufacturing, and marketing) according to different SC function specializations, spanning the end-to-end of the SC.

Based on this, Haier went on to flexibly combine service modules of different SC functions into themes, to offer diversified SC integration solution packages. These themes included customer-to-manufacturer (C2M) solution, start-up incubation solution, and supply chain financing (SCF) solution. Thus, Haier decomposed the whole SC through the identification of new, specialized SC functions and the expansion of SC solutions, sometimes in different combinations (see Figure 4).

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BMI-step2-1 (value proposition): Providing external firms (in different SC roles and in different industries) project-based customized SC solutions via Haier's new independent SC system, COSMO

Based on the SCIs described above, at the end of 2016 Haier launched its one-stop B2B SC solution system, COSMO. The system provides various professional SC solutions for different industrial clusters and firms in different SC roles. As a pilot, for each empowered industry, Haier selected a typical firm as the first business customer, and built a hands-on project service team specifically for that firm.

According to our interviewees, although Haier's SC capability has been largely productized and modulized by SCIs in step1 and step 2, these service modules are not enough to support Haier to provide professional SC solutions in the solution market. More diversified service modules within and cross industries need to be developed, through the accumulation of demands in project-based customized solution provision during the initial phase of COSMO.

BMI-step2-2 (service architecture): Establishing a hybrid architecture between

platform and closed-loop SC integration

The architecture established in step 1 was based on the “side-by-side connection” of the single-function SC platforms, but in step 2 seven SC functions were closed-loop integrated in terms of the “three flows” (of capital, logistics, and information). The architecture of COSMO is in fact a hybrid between a platform and a SC integrator. The solutions of a single SC function can be expanded vertically by attracting more and more third-party service modules through the platform structure, and across the seven SC functions the solutions can be expanded horizontally by integrating more and more SC functions.

Such hybrid architecture can ensure that, on one hand, in order to promote open innovation, external resources can be managed in a loosely coupled manner. On the other hand, for some core partners, the SC functions need to be integrated more closely. Management of the cross-function SC is largely based on the control of the “three flows”, especially the information transformations among different SC functions. There are two sets of such information transformations: customer needs transformed into product design solutions, and product design solutions transformed into a master production plan, with a detailed materials requirements plan and production planning and scheduling, and the production process is visualized.

BMI-step2-3 (governance mechanism): Transitioning from a buyer-seller relationship to co-production

In our case study, the interviewees emphasized “interacting value” when they described what kind of customers are selected by the COSMO. Compared with the governance mechanism in step 1, which focused on “my partners and I serve you,” or essentially a service transaction relationship, in step 2 the governance mechanism for business customers was focused more on “we interact for service co-production.”

Compared with the single-function SC solutions in step 1, the specific themes of the cross-function SC solutions are more complex, non-standardized, and need more interactions with customers. In order to achieve its own customized solutions as well as those of third-parties, Haier requires interaction with customers for every SC function.

Such “parallel interaction” also puts demands on customers, in that it requires them to be able to lead and contribute knowledge to the solution, that is, to engage in solution co-development and achieve a co-specialization by interaction with solution providers. Haier therefore chooses leading firms or firms with years of industry experience as business customers in various industries. For instance, the first customer in the clothing industry is a top-tier garment supplier and original brand manufacturer with more than 30 years of experience in the industry; customers in the building ceramics industry are firms that have strong R&D capabilities; in the machinery industry, some old state-owned enterprises are chosen as the customers; in the mobile homes industry, the customers Haier chose was the leader of this industry. All these business customers make big contributions to solution development and deployment (see Table 4).

One interviewee pointed out that:

“*Transactions must become platforms for value interaction. There were some* *transactions based on buying and selling, which can be found in the traditional economic era, but they are less important in the Internet era. Without the added value generated by interaction, as long as there is no platform for value interaction, it should not exist.*" (Senior manager of COSMO, quoting the words of the chairman of Haier group)

Another interviewee emphasized that:

"*COSMO is a multilateral value co-creation platform and an ecological closed loop. All resources, capabilities, and technologies can be released, but only if the external enterprise can create value at any point of the loop can it exist in the platform.*" (VP of the Haier group)

--------------- insert Table 4 about here ----------------

Interaction between SCI and BMI in step 2

In step 2, the interaction between SCIs and BMIs was mainly manifested as SCIs supporting BMIs. Two SCIs, (1) the methodology development for basic cross-function SC integration solution, and (2) the expansion of new SC functions and specialization of integrated solutions, jointly provide conditions for the updated value proposition, the hybrid service structure, and the new governance mechanism for customers.

Step 3: SCaaS (2018-present)

Executives of COSMO recognised that, as their SC solutions attract more and more business customers, the service approach based on projects greatly limits service efficiency. Furthermore, there is a lack of communication between project teams providing solutions to different industries. Therefore, Haier started to change the project-based customized SC solutions to modular-based, mass customized SCaaS in terms of rebuilding the service architecture, interface, and processes, through SCIs and BMIs.

SCI-step3-1: Building a modular SC resource pool

Based on the module development in specializing single-function SC solutions in step 1, specializing cross-function SC solutions in step 2, and the project-based customized SC solution provision in step 3, Haier developed a modular resource pool, which structurally accommodates the broadest coverage and complexity of diverse SC service modules. Thus, Haier can provide a flexible and diverse portfolio of modules for external firms in different industries.

According to the case data, the resource pool has three characteristics:

First, it contains three types of modular resources (and their providers): the cross-industry common modules, the within-industry common modules, and the within-industry customized modules (as shown in Figure 5). The cross-industry common modules are mainly represented by technical resources (such as the cloud server, algorithm, database, etc.) and methodologies (such as the standards for SC integration, the process for developing mass customized SCs, etc.). The within-industry common modules are mainly represented as industry-specific mobile APPs, jointly developed intellectual properties, and other tangible assets. The customized modules are mainly provided by internal and external suppliers which have customized service capabilities.

Second, the modular resource pool structurally accommodates the broadest coverage and complexity of SC services. In terms of the depth of the SC service, it covers all the key activities within each SC function. In terms of the breadth of the SC service, it undertakes many of the SC roles as it can (such as developer, supplier, manufacturer, distributer, logistics provider, customer services provider, etc.) across different SC functions.

Third, in addition to the SC service category genealogy of the resource pool in both vertical and horizontal directions, COSMO's experience in serving different industries is also amalgamated to form the development standards for common modules, customized modules, and their combinations (see Figure 5).

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BMI-step3-1 (service architecture): Front-back stage decoupling for the provision of mass customized SC solutions

In order to facilitate the implementation of service modules, Haier has also adopted the service architecture of front-back stage decoupling, that is, the front end focuses on the interaction with customers and the service experience, while the back end (i.e., the modular resource pool) focuses on the development of module components and service efficiency, and the two combine to realize mass customization of SC solutions.

Haier designed the front end as two types of interface for customer interaction. One type is the direct interaction between each project team and the business customer, to deal with complex service requirements. In this situation, the project team is responsible for assembling the modules into a solution. The other type is the specialized interactive interface of the industry platform developed by Haier for each industry it serves, which can deal with simple and common requirements, in the form of SaaS self-service. In this situation, the customer is responsible for assembling the modules into a solution. Depending on the complexity level of the service requirement, the customer will partly interact with the industry platform for some common modules and partly interact with the project team for some customized modules.

Interfaces of these different industry platforms connect to the same pool of resources; in other words, these industry platforms are the "reflections" of the parent platform (COSMO) in different industries. Thus, COSMO can "show different faces in different scenarios." In this way, customer interaction in different industries can be input into the resource pool to promote module innovation, and any innovations in customer interaction in one industry can also be quickly spread and applied to SC solutions in other industries.

BMI-step3-2 (value proposition): Providing external firms in different SC roles and in different industries with mass customized SC solutions

Based on the modular resource pool and the new service architecture, a new value proposition is established to provide external firms in different SC roles in different industries with modular and scalable mass customized SC solutions. Thus, COSMO can achieve a balance between service efficiency and the variety of customer needs in SC solutions.

SCI-step3-2: Standardizing the service process of a SCaaS

Based on the modular resource pool, upgraded service architecture, interface, and value proposition, COSMO summarized a standard “SCaaS” service process. According to the data analysis, the process can be summarized as the following four steps:

(1) ***Identification and decomposition of customer demand.*** The project teams decompose customer demand and identify which parts of that demand can be provided by the industry platform interface, and which parts should be provided by the project team.

(2) ***Coordination of modular resources.*** This involves determining which parts are to be taken from common modules and which parts need to be developed into customized modules. If customized modules are to be developed, it will be necessary to identify who will be the supplier - Haier itself or a core partner, or a peripheral partner in a loosely coupled relationship? The case data show that Haier has its own principle for such determinations. When coordinating multiple agents for the supply of a module resource, it examines whether the resource recombination is optimal in terms of “resources leverage”. One of interviewee at Haier said, “*After each interaction with customers, we think about whether there is any change in the combination of R&D, manufacturing, sales, and other functions of our SC, and in the resource pool.”*

(3) ***Development and deployment of the service portfolio.*** This involves combining the modules and the formation of a service portfolio for a SC solution.

(4) ***Feedback and module update.*** This involves customer feedback, and the formation of common modules from the customized modules. If the customer feedback has a common theme, it likely that more customized modules can be formed are into common ones, increasing service speed and freeing up more effort to make new customized modules, resulting in a positive feedback loop.

BMI-step3-3 (governance mechanism): Maximizing the interests of all stakeholders by achieving supermodular complementarity

The case data shows that in step 3, the change of value proposition is reflected in the deepening of value co-creation. That is, there is a shift in emphasis from co-production (or co-specialization) in step 2 to “maximizing the interests of all stakeholders” in step 3.

In step 2, the value created by the interaction was still limited to a role within a solution, benefiting only those parties involved in the interaction. (In other words, the value of the interaction was still for “our small group”, for example within the same industry.) At that point there were not the tools and mechanisms to enable value co-creation to expand to its fullest potential.

However, in step 3, through the establishment of the modular resource pool and the service architecture of front-back stage decoupling, the value created by the interaction in the development of some solutions can be better located within the common modules, or components of customized modules, and spread to other (such as cross-industry) customers' applications. This breaks down the barrier of value utility, so that the value of co-creation can have greater utility, and value co-creators also get greater benefits.

For instance, through the interaction with Haier, some customers also contribute to the modular resource pool by jointly providing new modules or components; here, the intellectual property is shared with Haier. An example of this is “Unified Ceramic”, a business customer of Haier COSMO in the ceramics industry, which jointly developed an anti-static ceramic tile with Haier for industrial use. Another example concerns “Compaksrv”, a customer of Haier in the mobile homes industry, which jointly developed a mobile home camping and travel service brand named “Sindar” with Haier; and a final example is presented by “Aspop Jeans”, a customer in the clothing industry, which jointly developed with Haier a jeans intelligent factory service that offers mass customization (see Table 5).

Many business customers have now become modular service providers in the resource pool. This has changed the relationship between customer and Haier COSMO from “unique complementarity, or co-specialization” (i.e., the value of co-creation is specific and is used for certain bounded solutions) in step 2 to “supermodular complementarity” (i.e., the value of co-creation is no longer limited to its own application, but also can be spread and applied to other customers and other fields, so that value co-creators can gain mutual enhancement) (Jacobides *et al*., 2018).

One interviewee pointed out that,

> *“The best resources in the world are definitely not yours. What if you try to get them in? The interests of all stakeholders in the ecosystem must be maximized.… In the past, it was possible for me to maximize my interests, but I don't care if*

others maximize their interests. Now it has to be all about maximizing their interests. People are willing to invest and contribute only if they can get the most value from their contributions." (VP of the Haier group)

"Everyone is a combination of 'independent ego' and 'ego serving others'. The 'independent ego' means, I am an independent player, and I have unlimited potential. The 'ego serving others' means, in the creation of the best service experience, I can unleash my full potential and get self-actualization." (VP of the Haier group)

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Interaction between SCI and BMI in step 3

In step 3, the interaction between SCIs and BMIs mainly manifests as mutual support. Specifically, the mass customized SC solution system, including the modular resource pool, the service architecture of front-back stage decoupling, and the design of two types of interactive interface, jointly help to capture and amplify the value co-created in the interaction between customers and Haier COSMO, thereby maximizing the interests of all stakeholders by achieving supermodular complementarity.

5. Discussion and Propositions

In this section, we clarify the findings presented in Section 4 and provide a conceptual framework (see Figure 6) and propositions to summarize the theoretical insights.

-----------------------------------Insert Figure 6 about here------------------------

First, the case findings reveal the formation mechanism of SCaaS. Generally, the

SCaaS is a SCI (building an end-to-end modular SC capability to serve its own PSS)-driven BMI (transforming SC capability into SC solutions to serve external firms). In this transformation, three steps of interactive implementation of SCIs and BMIs promote the formation of SCaaS. In step 1, in order to gather information on external demand, thus stimulating innovation and input from third parties, Haier started to provide single-function SC solutions (BMIs), which led to methodology development and specialization of these solutions (SCIs). In step 2, the methodology development and specialization of cross-function SC solutions (SCIs), in turn led to the hybrid structure of platform and SC integration, and the deepening of the relationship between Haier and its business customers (BMIs). In step 3, in order to explore how to change a project-based customized solution into a mass customized solution, the service architecture and processes were re-organized (SCIs), facilitating the generation of a new value proposition and promoting the relationship between Haier and business customers, which again changed from one based on unique complementarity to one based on supermodular complementarity (BMIs). In summary, the role SCIs play is productization of the SC capability. The role BMIs play is implementation of the SC solution products. Through the three steps of interaction between SCIs and BMIs, Haier upgraded its SCM from an operational concept to a business model and strategic concept, and developed the SCaaS framework.

Second, the case findings also reveal two conditions to estimate when SCaaS can be achieved. One condition is that, only by helping both the supply side and the demand side to achieve supermodular complementarity can the interests of all stakeholders be maximized. The SCaaS can be realized only by maximizing the interests of all parties. The other condition is that the architecture of a SC service system must achieve front-back stage decoupling and two types of interfaces to support the mass customized SC solutions. Unlike a typical cloud service, which is characterized by "autonomous interactive interfaces, plug-and-play flexibility, and virtualized resources provided by the Internet" (Leukel *et al*., 2011), the cloudification of the SC service, i.e., SCaaS, places more emphasis on the ambidexterity of utilization of both the platform and SC integration, and both the automated and enacted interactive interfaces. The core of the SC solution is the integration of the "three flows", as well as upstream and downstream knowledge transformation and other tacit knowledge and ability.

Therefore, we propose that:

P1. SCIs and BMIs interactively promote the formation of SCaaS. In a broad sense, SCaaS is a new business model driven by the resources and capabilities accumulated through SCIs. In its formation process, SCaaS is a result of three sequential rounds of interactive promotions between SCI and BMI. Specifically:

P1a. In the first round, the commercialization of single-function SC solutions (BMIs) lead to the modularization and specialization of single-function SC solutions (SCIs). In the second round, the modularization and specialization of cross-function SC solutions (SCIs) lead to an independent SC system and new value proposition of business solutions (BMIs).In the third round, SCIs and BMIs mutually reinforce each other, *resulting in the final SCaaS.*

P1b. A SCaaS can be identified when: 1) the supermodular complementarity with both external resource suppliers and customers is appeared; and 2) a front-back stage decoupling architecture with two types of customer interfaces is developed.

The case findings also reveal the roles and key activities for each role that the SCaaS can help to manage. These findings also indicate how SCaaS can operate and what resources and capabilities should be used in providing the mass customized SC solutions.

Therefore, we propose that:

P2. A SCaaS offers a matrix of SC service modules which cover all major functions of a SC, and are co-created by all major SC roles like suppliers, manufacturers, brand companies, distributors, logistics providers, designers and R&D professionals. Business customers can freely configure these modules to satisfy their varying needs. As to the details, in specific:

P2a: A service architecture featured by a decoupled front-back end is built to manage the key activities of all major SC roles.

(1) The back end is a modular resource pool covering a variety of SC resources (from within-function to cross-functions). The resource pool incorporates three types of modules (cross-industry common modules, within-industry common modules and customized modules), which serve as the "building blocks" to "construct" SC solutions per the business customer's needs.

(2) The front end is a customer interface which allows two types of interaction. One is

for the direct, offline interactions between a cross-organizational project team and a business customer. The other is the human-computer interfaces in each industry sub-platforms. Depending on the complexity level of service requirements, a business customer may resort to both types of interaction in one solution. That is, to interact with the project team for using customized modules, and to use common modules in a simpler, SaaS-style way.

P2b: The business customer in a SCaaS can go beyond benefiting its own supply chain. That means it can co-create value with the SCaaS leader for meeting the demands of other customers. In this way, the business customer will become a new third-party resource supplier of SCaaS.

Besides, the findings of the case analysis also reveal the detailed service process of a SCaaS. We propose that,

P3: The service process of a SCaaS contains the following four steps:

Step 1: Processing with customer demands: To analyse the customer demand, and identify which parts of demand should be addressed by the project team, and which parts of demand can be satisfied via the human-computer interfaces.

Step 2: Modular resources coordination: Determining which parts are to be taken from common modules and which parts need to be developed into customized modules. For developing customized modules, it is important to identify the potential supplier – the platform itself, a core partner, or a peripheral partner in a loosely coupled relationship.

Step 3: SC solution development and delivery: Configuring and combining the modules needed to form a SC solution (typically a service portfolio), and deliver it to the business customer.

Step 4: Feedback and upgrading: the feedback of business customer may trigger a next round of module upgrading in the resource pool. With the aggregation of similar feedbacks, some customized modules may be re-designed into common ones, improving the future response speed while reducing the project teams' workload (they are thus able to develop new customized modules), resulting in a positive feedback loop.

Through the above propositions, we summarize the definition of the SCaaS from the S-D logic perspective:

Definition of SCaaS: A SCaaS is a service and value co-creation facilitation framework which uses the cloud idea as a metaphor for understanding a new business model based on a loosely coupled SC network. In this framework, the resources and capabilities of a multi-party SC network are modularized, and then grouped into mass-customized solutions provided to customers. The customer can also co-create values for other customers and change its own role into that of a third-party resource supplier.

6. Conclusions and implications

This paper has three main research findings. First, we revealed the formation process of SCaaS in terms of SCIs, BMIs and their interactions, as well as the indicators that represent the final establishment of SCaaS in the formation process. Our longitudinal case study showed that the relationship between SCIs and BMIs in forming the SCaaS is dynamic and mutually reinforcing. On one hand, BMI often leads to a higher-level (more depth and/or breadth) of SCI. On the other hand, SCI often creates greater value to more SC roles through enhanced SC capability, and thus triggering the upgrading of business model. This is a new discovery on servitization research, since previous studies mainly focus on "pre-existing models" (with an emphasis on from less to more servitized or service-dominant), instead of producing "yet another model" (Brax and Visintin, 2017). As a response, this study identifies SCaaS through turning SC capability into a solution service for a new track of customer, and thus creating a new business model.

Second, we combined S-D logic with the current cloud and engineering perspective to expand the understanding of SCaaS, as well as the roles and activities it incorporates. In specific, this study views SCaaS as a mass customized SC service system with particular emphasis on value co-creation activities among complementary SC members. This definition captures some new characteristics of SCaaS at an ecosystem level. The current cloud and engineering perspective, however, is still valid in demonstrating how the resources and capabilities in a SCaaS are organized for facilitating value co-creation. In doing so, we answers a recent call for investigating how value co-creation activities facilitate systemic and synergistic effects in complex networks rather than in a dyadic relationship (Lusch *et al.*, 2010; Lusch, 2011; Constantinides *et al.*, 2018).

Third, at a service operation level, this study proposes a detailed service process of SCaaS when meeting with specific customer demands. Our case findings show that at the implementation level, a SCaaS service process may contains four sequential steps, from processing customer demands, to coordinating modular resources, to configuring SC solutions and to the customer feedback and future upgrading of the resource pool. This provides a more contextualized understanding on value co-creation activities among multiple interaction processes and collaborative mechanisms.

This study has some managerial implications as well. First, to improve the competitiveness, manufacturing enterprises need to put efforts into servitization. In addition to increased strategic and operational service emphasis on the “pre-existing models”, this study shows that another servitization way is to transform to a SCaaS. It builds on many years of accumulations on SC capabilities and SC related digital technologies, and requires several rounds of transformations in SCIs and BMIs.

Second, as a SCaaS leader, one should proactively affect the infrastructure, resources and capabilities, and relationships among different groups of participants of its SC network. The case shows that the SCaaS should not be considered as a “secondary business model” which is complementary to the “primary business model”: it is an approach for building the connections needed within a business ecosystem.

Third, as a participant in a SCaaS, one should know how to utilize modular resources in the SCaaS, and how to modularize its own resources to be applied in the SCaaS. The findings indicate that business customer in a SCaaS can go beyond benefiting its own SC. It can co-create value with the SCaaS leader for meeting the demands of other customers. In this way, the business customer can become a new third-party resource supplier of SCaaS.

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Table 1 Evolution of SCM-related concepts: a comparison

Term	SC for traditional manufacturing	SC for supporting PSS	SCaaS
Conceptualization	• An resource and operation management tool for supporting the core business	• An resource and operation management tool for supporting the core business	• An independent business model in parallel to the core business • A cloud service by newly utilizing SC capability
Theoretical perspectives	• Engineering design	• S-D logic	• S-D logic+ cloud service
Focus	• Cost/ risk/ efficiency in production and service offering process	• Value co-creation facilitation and business ecosystem maintaining	• Value co-creation facilitation and business ecosystem maintaining
SC structure	• Linear	• Close-looped	• Close-looped
SC network	• Strong or rigid ties between suppliers, customers, and other SC partners	• Loose ties between suppliers, customers, and other SC partners	• Loose ties between suppliers, customers, and other SC partners
Examples	• SC in the traditional manufacturing mode (Detailed processes of day-to-day execution for connections between planning, R&D, material purchase, manufacturing, marketing, logistics, customer service, etc.)	• SCs for smartphone, household, and automobile industries	• Commercialized, mass customized SC services provided by JD.com and Haier COSMO
Literature	• La Londe and Masters (1994); • Mentzer *et al*. (2001); • Mass *et al*. (2014).	• Resta *et al*.(2017); • Yang *et al*.(2018); • Brax and Visintin (2017).	• Leukel *et al*. (2011).

Table 2 Summary of interviews

Case	Respondents' titles	Date	Duration (hours)
Haier (group level, COSMO level, and other BUs)	VP of Haier group (in charge of the SCM), President of Haier COSMO	Aug. 2, 2014	2
		Dec. 12, 2015	2
		Jul. 21, 2016	1
		Apr. 11, 2018	1.5
		Jun. 6, 2018	1
		Aug. 22, 2018.	1
		Jul.10, 2019	1
	Direct of the interactive design platform	Aug. 22, 2018.	2
	Direct of the R&D platform	Aug. 22, 2018.	2
	Director of the intelligent manufacturing platform	Aug. 23, 2018.	2
	Director of the procurement platform	Aug. 23, 2018.	2
	Director of the customer services platform	Aug. 23, 2018.	2
	Director of intelligent SCM, BU of home appliances	Jun. 11,2018	2
		May 30,2019	4
		Jul. 9, 2019	1.5
	Senior manager of intelligent SCM, BU of home appliances	Jun. 6, 2018	2
		Jul. 10, 2019	2
	Senior manager of COSMO (in charge of solution promotion)	Jun. 6, 2018	2
		May 30,2019	4
	Senior manager of COSMO (in charge of internal coordination)	Aug.22, 2018	2
		Jul.10, 2019	1
	Senior manager of Haier intelligent manufacturing research institute	May 29, 2019	2
		Jul. 8-10, 2019	3
		Aug. 3-5, 2019	3
	Project team leader for the agricultural industry service, COSMO	Jul. 10, 2019	1.5
	Project team leader of the machinery industry service, COSMO	Jul. 10, 2019	1.5

		Director of SCF BU	May 23, 2016	2
			Dec. 22, 2018	3
			Aug. 3-5, 2019	2
Dyadic interviews for the mobile homes industry service of COSMO	Project team for the mobile homes industry service	Team leader	Jul. 10, 2019	2
		Senior manager for client interaction	Jul. 9-10, 2019	6
	Business customer: Compaksrv Co., Ltd.	President	Jul. 9, 2019	1
		VP	Jul. 9, 2019	2
		Manager	Jul. 9, 2019	3
Dyadic interviews for the ceramics industry service of COSMO	Project team for the ceramics industry service	Team leader	Jul. 8, 2019	3
		Senior manager for Clients in North China	Jul. 8, 2019	2
		Senior manager for Clients in South China	Jul. 10, 2019	2
	Business customer: Unified Ceramics Co., Ltd.	General manager	Jul. 8, 2019	2.5
		Director for production	Jul. 8, 2019	2
		Director for logistics	Jul. 8, 2019	2.5
Dyadic interviews for the clothing industry service of COSMO	Project team for the clothing industry service	Team leader	Aug. 5, 2019	2
		Senior manager for client interaction	Aug. 5, 2019	2
		Senior manager for technology support	Aug. 5, 2019	2
	Business customer 1: Qingdao Global Garment Co., Ltd.	CEO	Aug. 5, 2019	2.5
	Client 2: Aspop Jeans Co., Ltd.	CEO	Jul. 8, 2019	2.5
Total				Total: 97
Other material				
Meeting with participant observer and joint workshops			2014-2019	10 meetings
Confidential company documents and Marketing communication material			2014-2019	22pages

Source: Authors' own elaboration based on the interviews

Table 3. Overview of data collected through observation and joint workshop

Event, participants	Date	Theme or focus
International Conference of Supply Chain and Operations Management (ICOSCM 2014) (n>300)	Jul. 22-24, 2014	Best practices in SCM of Haier (Keynote speech)
Academic & Industrial Joint Seminar with Haier on Supply Chain and Service Innovations (n=24)	Mar. 30-31, 2015	Service design and service innovation in the network environment
Global Summit of Supply Chain and Service Innovation in CEIBS 2015 (n>600)	Oct. 26-27, 2016	Discuss the transformation of business models driven by SC innovations
Case development workshop with Haier and CEBIS Center of Innovation in Supply Chain and Service (n=8)	Dec. 18, 2016	Discuss the transformation from mass production to mass customization
Joint International Conference with Haier (ICOSCM 2018) (n>400)	Jul. 19-22, 2018	Digital Supply Chain and Intelligent Manufacturing
Academic & Industrial Joint Symposium on Supply Chain and Service Innovations (n=40)	Apr.13-16, 2019.	Platform-based service innovation and system design of COSMO (Keynote speech)
ICOSCM 2019: Supply chain Innovation and Internationalization.	Jul. 19-22, 2019	Service innovation of COSMO (Keynote speech)
Forum on Cross-Border Supply Chain Innovation in the Digital Age	Nov. 8, 2019	Best practice of iHaier platform (Single SC operation platform of procurement) and the application to COSMO (Keynote speech)
EMBA Real Situation Learning Course for Best Practice on Supply Chain Innovation in Haier	Jul.-Dec. 2019	Best Practice in SCI and BMI
Joint SCM Online Course Design and Development with Haier	Jul.-Dec. 2019	Best Practice in SCI and BMI

Table 4. Co-production of Haier and its business customer in step 2

Customers	SC solution services from Haier		Co-produced value
Compaksrv (the mobile homes industry)	Customer service solution	Extend the after sales service, connect customers with vehicles, camps, and travel services together	• Order volume increased 62%
	Procurement solution	Gather the needs of other mobile homes enterprises, conduct intensive procurement for 8 kinds of bulk materials, and concentrate the suppliers of mobile homes tent, furniture and vehicle frame in a special industrial park.	• The procurement cost of some materials was reduced by 12%, and the comprehensive procurement cost was reduced by 7.3%
	Intelligent Manufacturing solution	Help Compaksrv to achieve process optimization, production cycle balancing, and lean production management.	• The product delivery cycle was shortened from 35 days to 20 days • The pass rate of one-time delivery has been increased from 95% to 97%
	Logistics solution	Developed a cross-border logistics system for the mobile homes industry, through which decentralized logistics needs of different mobile homes enterprises are brought together intensively.	• Reduction of logistics cost
	Interactive design & C2M	Help Compaksrv directly connect with users, understand user needs, and introduce module providers to participate in product design to promote the formation of mass customization needs.	• Achieved better quality control by reducing ten thousand components to one thousand modules • Customer satisfaction was enhanced.
	SCF	Haier provides SCF services to Compaksrv by controlling its SC.	• Reduction of financing costs
Unified ceramic (the ceramics industry)	Intelligent Manufacturing solution	Help Unified ceramic upgrade production line and reengineer the operation flow through SC digitalization.	• Production costs fell by 7.5%：12 RMB/piece->11.1RBM/piece • Product quality improved 4.5%： 95% -> 99.5% • Unit price of products increased by 17%： 13.3 RMB/piece ->15.6 RMB/piece
	R&D	Under the pressure of environmental protection and energy saving, guide Unified ceramic to shift the R&D focus to the industrial ceramic tiles.	• Sales rose 30% against a 23% drop in industry sales • Corporate profits also rose 32 %
	Customer service solution	Connect ceramic tile production with logistics service, installation service, decoration service, and related supervision service to expand the market of ceramic tile after service.	• Customer satisfaction was enhanced.
Aspop Jeans (the clothing industry)	Intelligent Manufacturing solution/ C2M	Help Aspop to improve flexible production capacity, to realize the rapid return of small orders in fast fashion industry; introduce board library to integrate customer customization needs and realize mass customization.	• Per capita productivity increased by 30% ; Profit per product increased by 200% • The product delivery cycle was shortened from 45 days to 7 days
	Customer service solution	Enhance the interaction between Aspop, its retailers and consumers by designing full process experience with user participation.	Increased the responsiveness to the market change
	Interactive design solution	Introduce the hardware, software and scene of 3D fitting, as well as the connection with the production link.	• Customer satisfaction was enhanced • Become one of the first collaborative apparel network manufacturers of Amazon.com

Table 5. Common modules Haier and its customers co-created and applied to other customers' applications in step 3

Value co-creators	Customized modules	Common modules	New customers of the common modules
Compaksrv and Haier	Helped Compaksr to extend the after sales service, connect customers with vehicles, camps, and travel services together.	• Jointly developed a mobile APP for mobile homes travel service with functions of travel route planning, ticket booking, gas station location, food and drink around the camp, alarm and rescue services. • Joint designed standards for mobile homes camping area development and operation. • Jointly developed a mobile homes camping and travel service brand named “Sindar”.	• Applied to 150+ mobile homes upstream and downstream enterprises, 200+ camp service providers, as well as a number of financial and insurance institutions, mobile homes rental companies, and vehicle after-sales service providers.
Unified Ceramic and Haier	Helped Unified Ceramic to shift the R&D focus to the industrial ceramic tiles	• Jointly developed an anti-static ceramic tile for industrial use (joint intellectual property). • Jointly developed a high-end ceramic tile customized brand named “Tsing Tsuk”.	• Applied to 100+ traditional ceramic enterprises in terms of R&D and intellectual property solutions. • Attracted more than one thousand enterprises in different parts of the ceramic industry chain for co-developing the ceramic tile customized brand “Tsing Tsuk”.
Aspop Jeans and Haier	Helped Aspop Jeans to transform from mass production to mass customization	• Jointly developed an garment mass customization model factory • Jointly developed a mobile APP for Jeans customization • Jointly developed AI intelligent body-measure fitting system and other technology applications	• Applied to 2000+ traditional clothing enterprises in terms of mass customization transformation.

Appendix: Interview protocol

Table A1 for the sample firm

The list of meta-questions addressed in the face-to-face interviews with managers focuses on the evolution of SCIs and BMIs in the dynamic development of the sample firm.	
1.Introduction	• Purpose of the interview • Outline of the intended coverage of the interview • Description of the anonymity rule in the interview • General interview guidelines • Structure of the interview • Definitions of SCI/BMI and development of stages
2. Development of company	• History and milestones, phase divisions • Introduction of main businesses • Organizational structure • Other basic information: e.g. Headcount/ Revenue / Registered users / Monthly active users/ Types of customers, etc. • Detail of SC service products at every development stage
3. SCIs	• Description of every SC service product(or process) innovation from the interviewee's own experience • Driving factors (e.g. disordered demands? customer feedback?)/ targets/ design processes /performance of every SC service product (or process) or their innovations • Experiences (both successful and failed) in designing and innovating these SC services • Relationship between SCIs and BMIs.
4.BMIs	• Description of every BMI from the interviewee's own experience • Driving factors (e.g. disordered demands? customer feedback?)/ targets/ design processes /performance of every BMI • Experiences (both successful and failed) in designing and innovating these BMs • Relationship between SCIs and BMIs.
End of interview	• Socio-demographics: time in position, work experience, educational background, area of expertise, etc. • Thanking the interviewee

Table A2 for customers of COSMO

The list of meta-questions addressed in the face-to-face interviews with managers from business customer companies of the focal firm, focusing on the services received from the SC service provider (focal firm).	
1.Introduction	• Purpose of the interview • Outline of the intended coverage of the interview • Description of the anonymity rule in the interview • General interview guidelines • Structure of the interview
2. Relationship with the focal firm	• History and milestones, phase divisions • Introduction of main businesses • Organizational structure • Other basic information: e.g. Headcount/ Revenue / Registered users / Monthly active users/ Types of customers, etc. • Detail of relationship with the focal firm
3. Services received form the focal firm	• Description(comments) of every service provided by the focal firm from the interviewee's own experience • Driving factors (e.g. disordered demands? customer feedback?) of the need of the services • Performance comparison in before and after the service
4.Coordination with the focal firm	• What are the difficulties in coordinating with the service provider (focal firm)? How are these problems solved? • What kind tools/approach efficiently enhanced the coordination with the service provider? • Experiences (both successful and failed) in collaborating with the focal firm in innovating the services
End of interview	• Socio-demographics: time in position, work experience, educational background, area of expertise, etc. • Thanking the interviewee

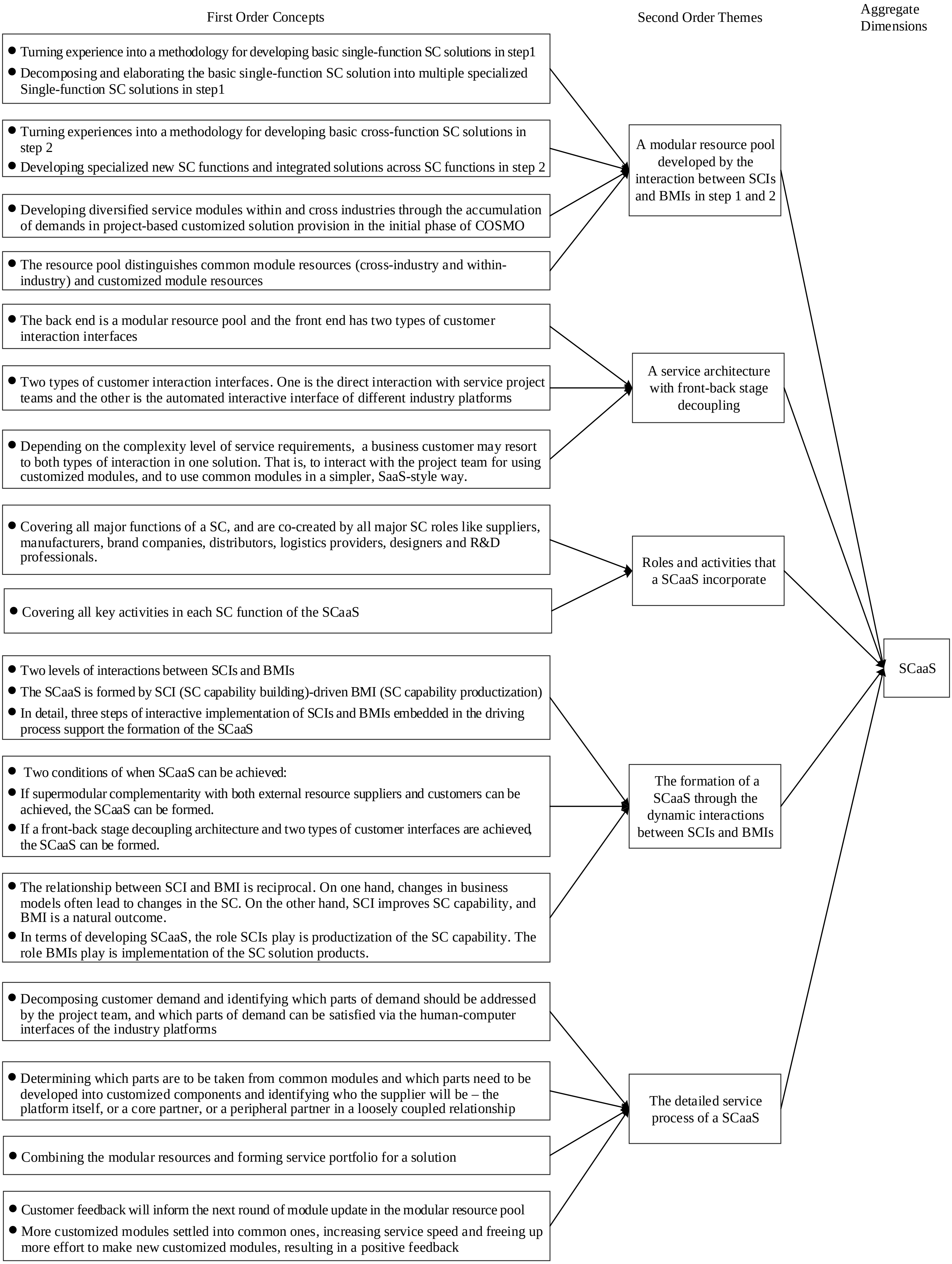


Figure1. Data structure

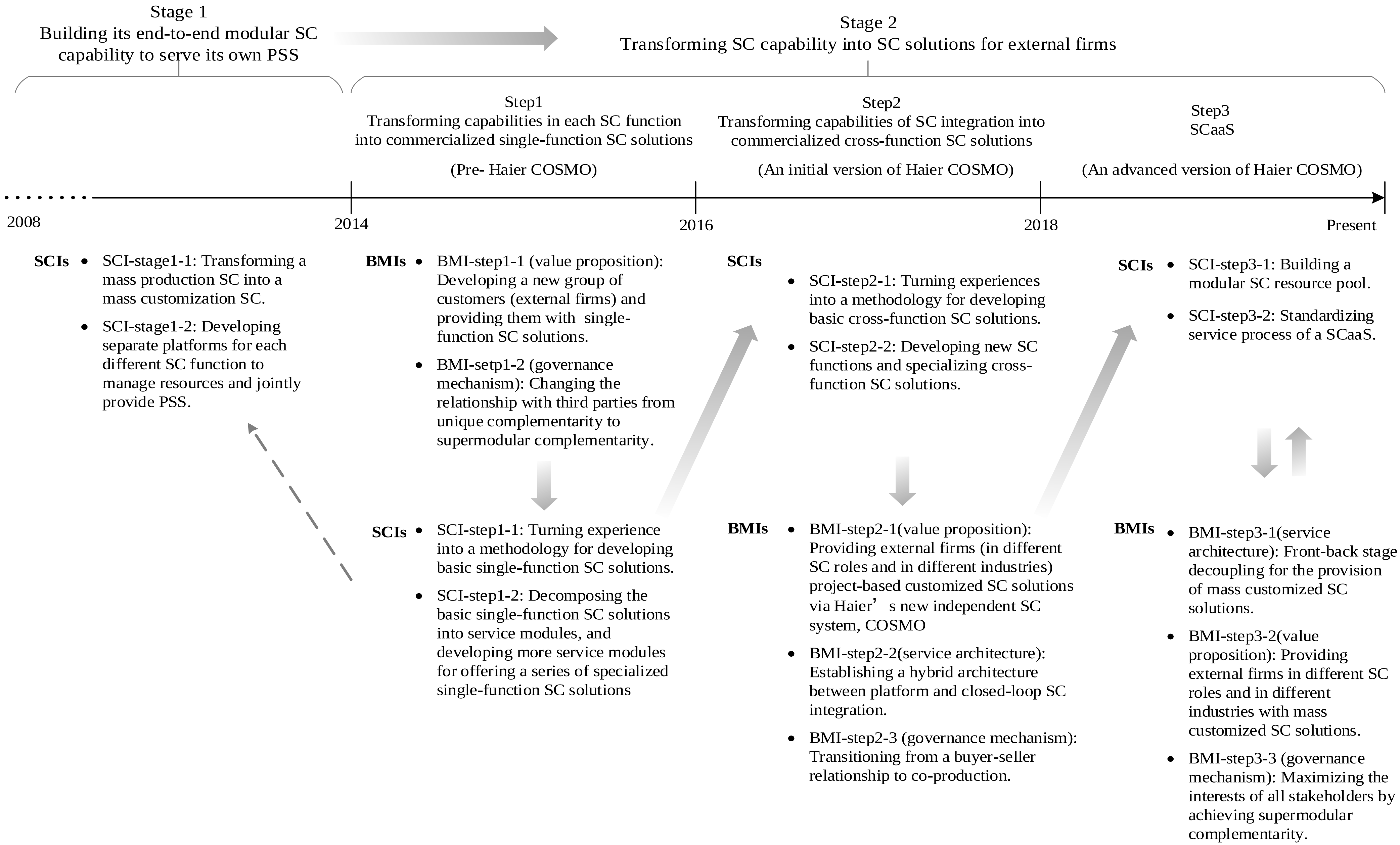


Figure 2. Interaction between SCI and BMI during the two stages and three steps

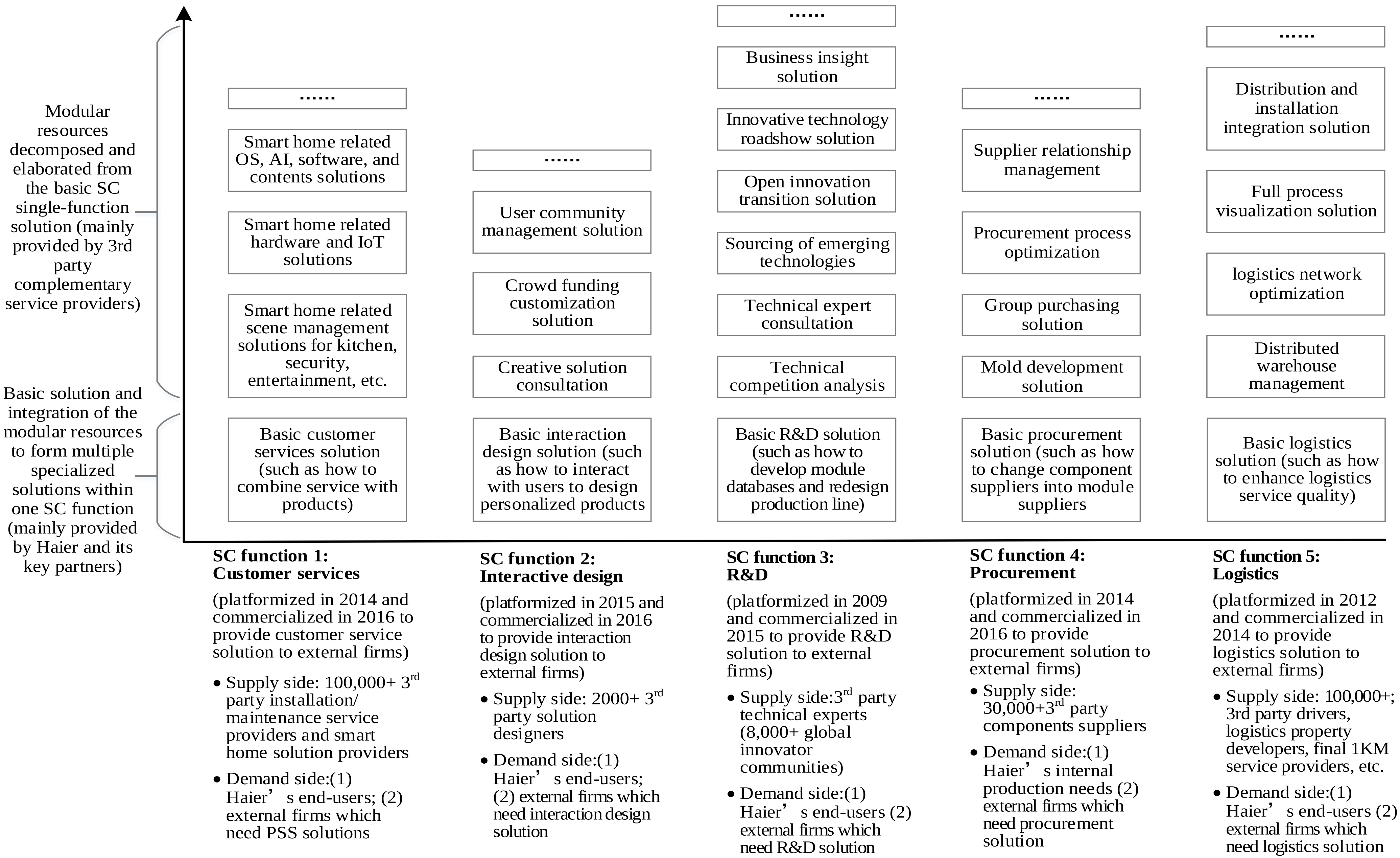


Figure 3. Decomposing and elaborating the basic SC single-function solution into multiple specialized solutions in Step 1

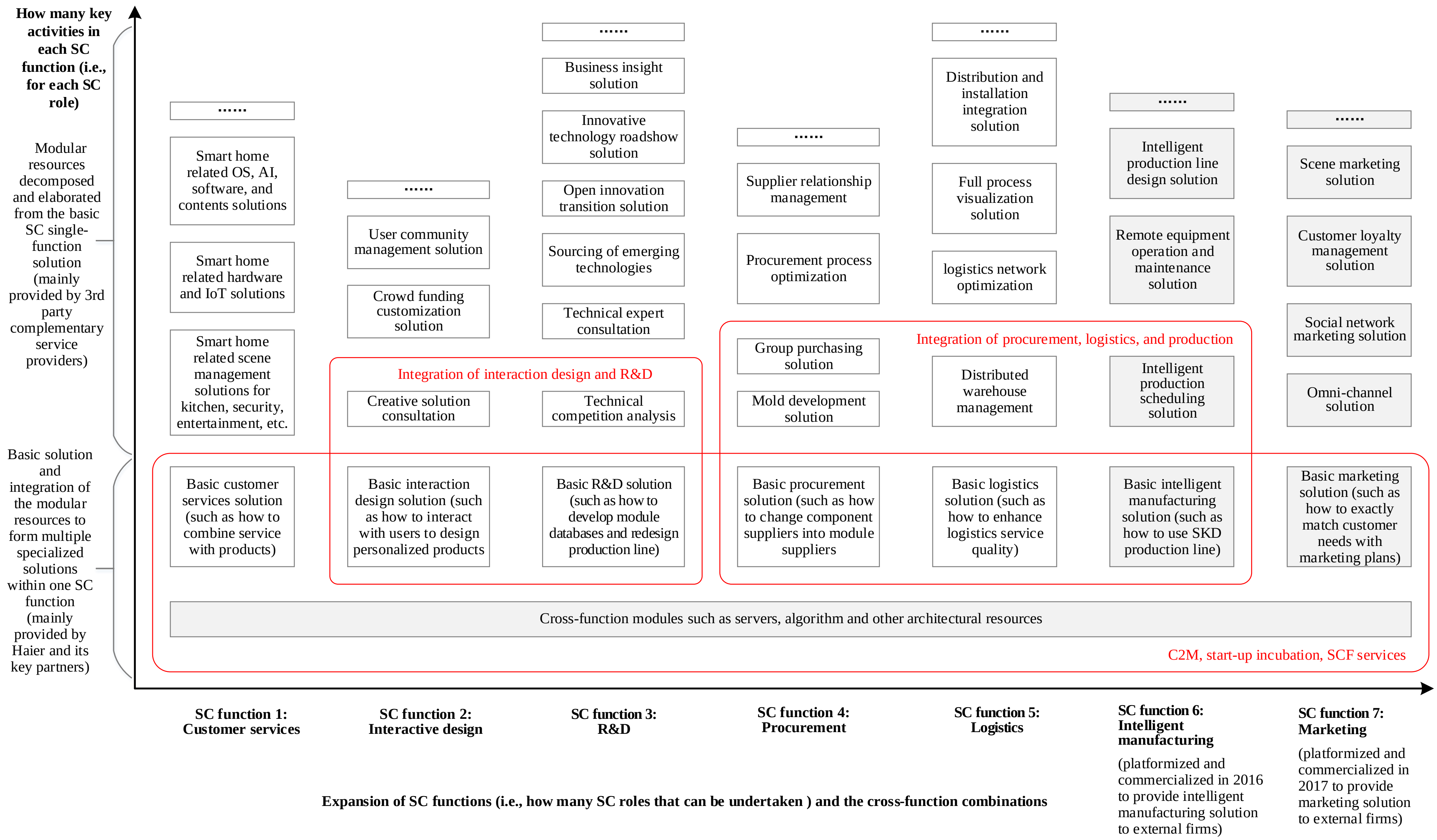
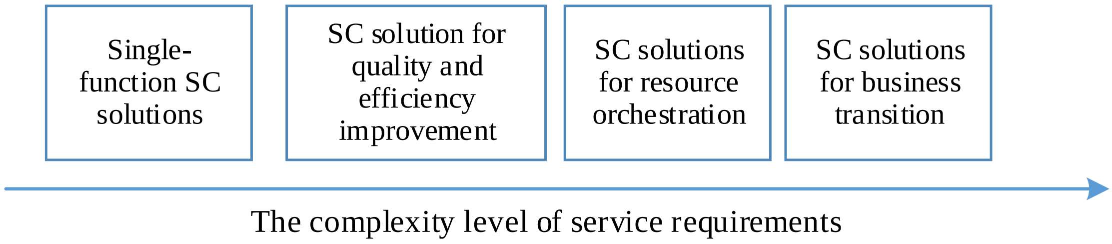


Figure 4. Developing specialized new SC functions and integrated solutions across SC functions in Step 2

Depending on the complexity level of service requirements, a business customer may resort to both types of interaction in one solution. That is, to interact with the project team for using customized modules, and to use common modules in a simpler, SaaS-style way.



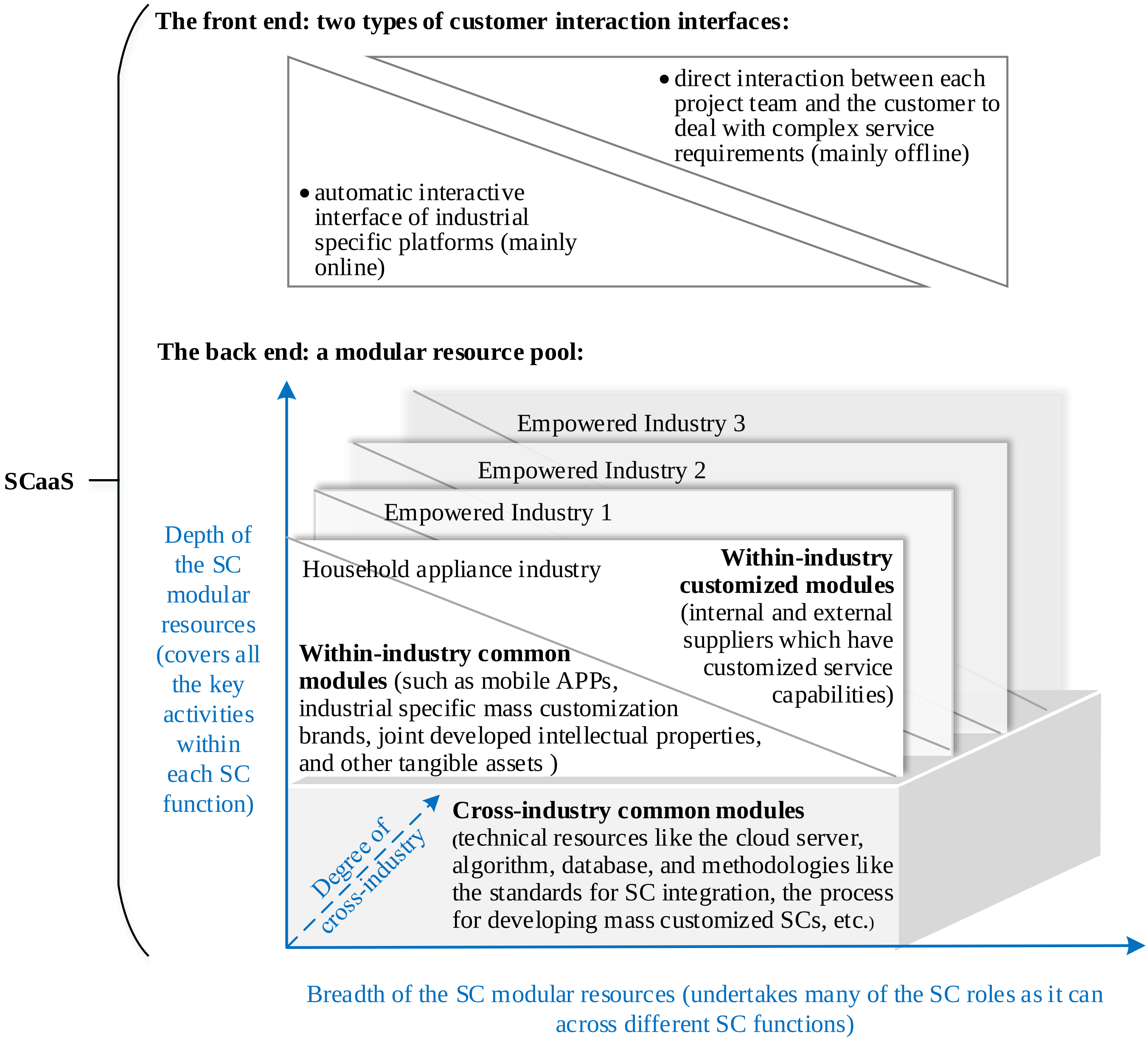


Figure 5. SCaaS in Stage 3

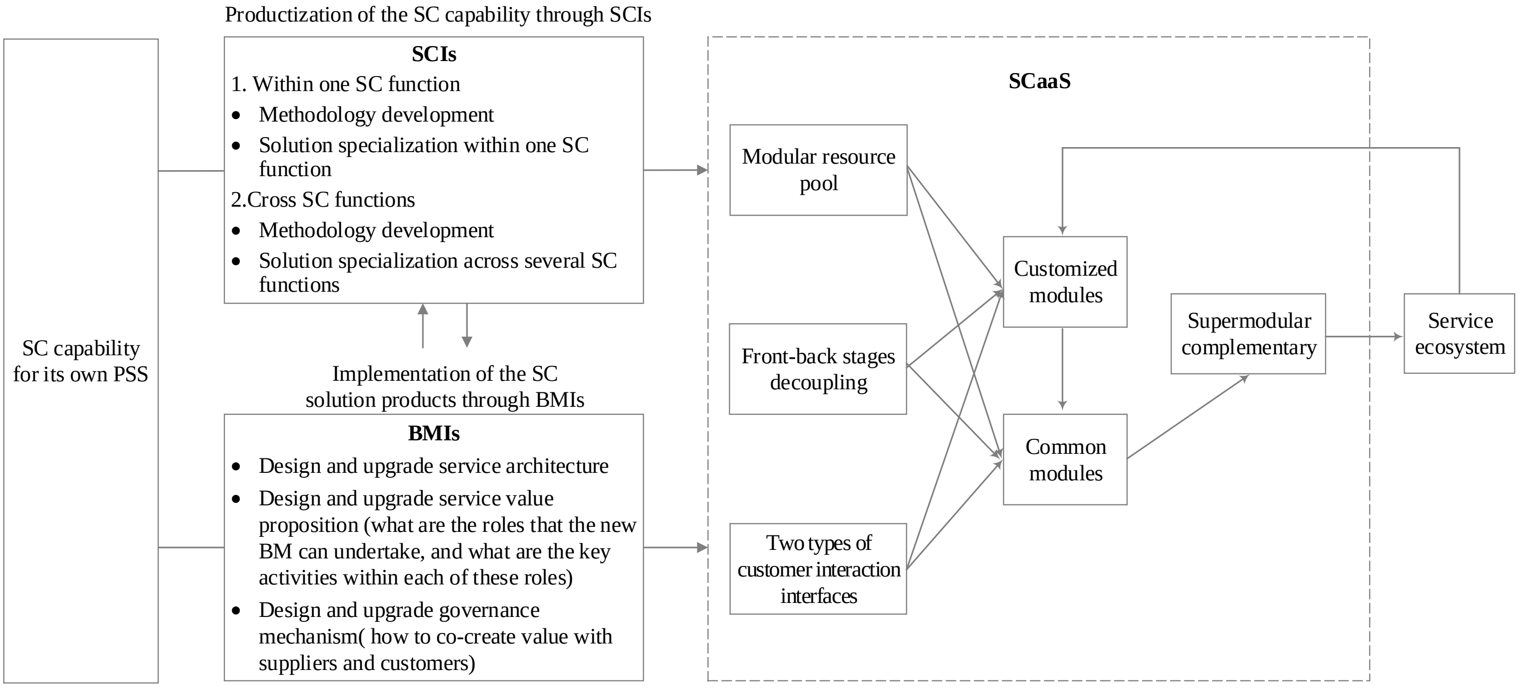


Figure 6. Conceptual framework of this study