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THEORETICAL ARTICLE

Value network analysis for complex service systems: a case study on Taiwan's mobile application services

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Abstract This paper aims to develop a service value network analysis approach based on system dynamics (SD) for analyzing the feedback structures that causes dynamic behavior of service value networks for value co-creation. The proposed approach defines the network objectives, identifies network actors and their interactions, builds SD models, conducts model tests, and evaluates possible policies that can be used to enhance the overall network performance. A case study of Taiwan's mobile application services is used to illustrate the developed methodology. The developed methodology can help managers represent complex interactions and feedback structures of the service systems for value co-creation. In addition, decision makers can use the models to evaluate alternative scenarios for better understanding the system behavior that can improve the policy design and evaluation. Finally, we recommend that the case company should sense the market development of mobile application services continuously and improve its service quality on both user and developer sides relentlessly for sustaining its market growth.

Keywords Service systems · Value networks · System dynamics · Mobile application services · Service science

1 Introduction

In recent decades, the transformation of industrialized economies from a manufacturing base to a service orientation has become a continuing trend. The service economy has become the driving force of economic growth of many developed countries (Spohrer et al. 2008). However, due to globalization, demographic

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changes, and technology advancement, the complexity and scale of services have become larger than before (Basole and Rouse 2008). Therefore, service innovation has become a major challenge for business, academics, and government. A better understanding of services from the systems perspective is needed to manage complex service design and delivery (Spohrer et al. 2007; Basole and Rouse 2008; Lusch et al. 2010; Badinelli et al. 2012). The key to creating successful service business models is to understand how value is co-created by a combination of firms in the value network (Basole and Rouse 2008; Lusch et al. 2010). With the value network concept, firms focus not on the company or the industry, but on the value-creating system itself, within which different network actors—supplier, partners, allies, and customers—work together to co-produce the customer value. Actors join in a value network by converting their expertise or core competence into tangible and intangible deliverables that have value for other actors of the network. However, organizations are confronted with many challenges in designing and managing complex service systems to achieve service excellence and economic viability (Briscoe et al. 2012).

An example can be found from the mobile telecommunication industry, which has transformed from value chains to value networks (Peppard and Rylander 2006; Pil and Holweg 2006; Zhang and Chen 2008; Mancuso 2012). Due to subscriber growth saturation and voice tariff competition, many mobile operators have been experiencing declining average revenue per user (ARPU) in the past few years (Peppard and Rylander 2006). Therefore, mobile operators have started pursuing innovation for providing value-added services (e.g., news, games, video, music, radio, applications, TV, etc.) for consumers that can thus lead to continued revenue growth (Raivio and Luukkainen 2011). However, due to the complex nature of the market, mobile operators do not have all the capabilities required to deliver value-added services. Thus, mobile operators face a challenge in how to integrate a cluster of network actors (e.g., software developers, content providers) for co-creating and delivering values to the end-consumer (Peppard and Rylander 2006).

Service research began in the early 1970s, generating various research streams such as service marketing, service operations management, human resource management, quality management, and various others (Moussa and Touzani 2010). More recently, the concept of service science, which adopts a system view of service, has emerged (Spohrer et al. 2007). As knowledge and competence are more diversified, the main challenge for firms is on how to design a service system that can integrate needs, resources, information, and objectives among actors involved in a service system to co-create and deliver values to customers. There are several studies on complex service systems, such as developing conceptual frameworks (Lusch et al. 2010; Badinelli et al. 2012; Briscoe et al. 2012), improving service operations, and analyzing value constellations among different actors (Kieliszewski et al. 2012). However, most studies ignore the factors of the feedback processes that would determine the dynamic behavior of complex service systems (Sterman 2000) for value co-creation; e.g., network externality existing in mobile telecommunications services (Gruber and Verboven 2001). Failing to consider feedback structures in the service system analysis may lead to a misunderstanding of service system behavior and ineffective decision making in designing and managing complex service systems (Badinelli et al. 2012; Briscoe et al. 2012).

This paper aims to develop a service value network analysis approach based on system dynamics (SD) for analyzing the feedback structures and dynamic behavior of service value networks for value co-creation. SD, which is grounded in the theory of nonlinear dynamics and feedback control developed in physics and engineering, is a method to enhance learning and understanding in complex systems through the use of feedback loops, stocks, and flows (Sterman 2000). The proposed approach defines the network objectives, identifies network actors and their interactions, builds SD models, conducts model tests, and evaluates possible policies that can be used to enhance the overall network performance. A case study of Taiwan's mobile application services is used to illustrate the developed methodology. The developed SD model consists of four subsystems: customer dynamics, pricing dynamics, application richness dynamics, and service quality dynamics. It can help mobile operators better understand the system structures and dynamic behaviors of complex mobile application services for value co-creation and assist them to evaluate and select suitable strategies for designing and managing their service systems for sustainable growth.

This paper is organized as follows. Section 2 reviews the literature on complex service systems. Section 3 introduces the proposed approach of service value network analysis. Section 4 presents an illustrative example of Taiwan's mobile application services. The simulation results and recommended strategies for the case company are also discussed. Finally, Sect. 5 concludes the paper.

2 Literature review

Several studies have highlighted the significance of service system concepts in modern service innovation and management (Spohrer et al. 2007; Basole and Rouse 2008; Badinelli et al. 2012). One of the main research streams emerging in recent years is service science, management, and engineering (SSME). It aims to discover the underlying principles of a complex service system and provide the structure and vigor for building a widely accepted and coherent body of knowledge to support ongoing innovation in service systems (Spohrer et al. 2007; Spohrer and Maglio 2008). In addition, Vargo and Lusch (2004, 2008) proposed the concept of service-dominant logic, which provides a new perspective and framework to view and manage service systems. From service-dominant logic, a service is the use of resources or competence for the benefit of another entity or actor (Vargo and Lusch 2004). The three primary principles of service-dominant logic are the conceptualization of service as a process, a focus on operant resources (knowledge and skills), and an understanding of value as co-creation between providers and customers (Lusch et al. 2008).

Service-dominant logic further motivates the need for the service system abstraction and the concept of a service system can be considered a vehicle for the study of value co-creation among different actors or entities involved in a service system (Spohrer et al. 2008). According to Spohrer et al. (2008), the service system is defined as “a dynamic value co-creation configuration of resources, including people, organizations, shared information, and technology, all connected internally and externally to other service systems by value propositions.” Other definitions of the service system can also be found in other studies (Vargo et al. 2008, Ng et al. 2009, Qiu et al. 2009, Spohrer and Maglio 2008). In addition, since interacting patterns among actors involved in the service system has become more complex, several researchers have proposed a conceptual model of the value network, which is the central concept in service dominant logic, for understanding and investigating the complex service system (Basole and Rouse 2008; Lusch et al. 2010). According to Lusch et al. (2010), the service value network is defined as “a spontaneous sensing and responding spatial and temporal structure of largely loosely coupled value proposing social and economic actors interacting through institutions and technology, to co-produce service offerings, exchange service offerings, and co-create value.”

Several research topics have been discussed in the literature of service science, such as value co-creation and collaboration, systems and networks, information and communications technology, and complexity (Ostrom et al. 2010; Briscoe et al. 2012). One key challenge in developing a new science of service is how to find appropriate methods for modeling complex service systems for value co-creation (Spohrer and Maglio 2008; Maglio and Spohrer 2013). If the complex service system can be modeled, then the decision maker can use the model to evaluate alternative scenarios, and understand the system behavior of service systems from complex interactions among different actors for improving their services to achieve sustainable change. For example, Caswell et al. (2008) proposed a network analysis methodology combining graph theory and network flows to evaluate the delivered value of the entire auto repair service system. Tian et al. (2008) proposed a quantitative framework integrating the value network modeling, game theory analysis, and a multiagent system, for performance evaluation of a B2B portal in the retail industry. The optimal pricing decision was determined by game theory, which does not consider the dynamic interplay among different business entities. Kieliszewski et al. (2012) applied the SPLASH platform, developed by IBM (Tan et al. 2012), to model value constellations of complex service systems. The developed composite model would allow for simulation of the service system which can be used to analyze the impacts of alternative modifications to the system through what-if scenario analysis. Badinelli et al. (2012) highlighted the importance of system thinking which may support the understanding of key issues in service management. The viable system approach was proposed for better supporting service system decision making in conditions of complexity and fuzzy models which were suggested to be adopted for making complex decisions under uncertainty.

From the above literature review of complex service systems, many studies have highlighted the importance of the service systems perspective for designing, implementing, and managing service innovation. Though some studies have indicated the necessity to consider nonlinearity in the complex service system (Badinelli et al. 2012), research on modeling feedback structures that cause nonlinear dynamic behavior of complex service systems is still lacking. This research intends to fill this research gap.

Further, the mobile application service is an emerging research area and several studies have been published, including mobile ecosystems (Feijóo et al. 2009; Ghezzi et al. 2009; Holzer and Ondrus 2010; Raivio and Luukkainen 2011), business models and development strategies (Chen and Cheng 2010; Gonçalves 2010; Müller et al. 2011; Cuadrado and Duenas 2012), adoption behaviors (Hong et al. 2008; Kimbler 2010; Kim 2012; Yan et al. 2013), contents as well as service design and development (Erman et al. 2011; Liu et al. 2011; Pousttchi and Hufenbach 2011; Kim and Lee 2012; Park et al. 2012; Son et al. 2013; Kim et al. 2014), etc. Though some studies have applied SD to examine the mobile telecommunication services (Pagani and Fine 2008), to the best of our knowledge, there is no research focusing on the dynamic behaviors of mobile application services in the literature.

3 Service value network analysis based on system dynamics

SD is a methodology for understanding complex problems where there is an underlying dynamic behavior affected by a certain set of feedback mechanisms. These methods have been used for over 30 years in various application domains, including: production management, project management, strategic management, education, energy and environmental planning, medical services, and public policy (Sterman 2000; Forrester 2007; Chung et al. 2010). Much of the art of SD modeling lies in discovering and representing the feedback processes and other elements of complexity that determine the dynamics of a system. Two SD modeling tools, the causal loop diagram and the stock and flow diagram, are used in this study and are introduced below. Please refer to Sterman (2000) for the modeling details of both tools.

3.1 The causal loop diagram

To better understand the system structure of the service value network which causes the dynamic behavior, this research uses the causal loop diagram to present circular chains of cause-and-effect structure in the service value network. The diagram consists of variables connected by arrows denoting the causal influences among the variables. The important feedback loops are also identified in the diagram. Figure 1 shows an example of the causal loop diagram.

Variables are related by causal links, shown by arrows. Each causal link is assigned a polarity, either positive (+) or negative (−) to indicate how the dependent variable changes when the independent variable changes. The important loops are highlighted by a loop identifier which shows whether the loop is a positive (reinforcing) or negative (balancing) feedback. For example, Fig. 1 shows a reinforcing loop that indicates the indirect network externality in the mobile application market, where the increased developer installed base increases application variety that increases the user installed base which, in turn, increases

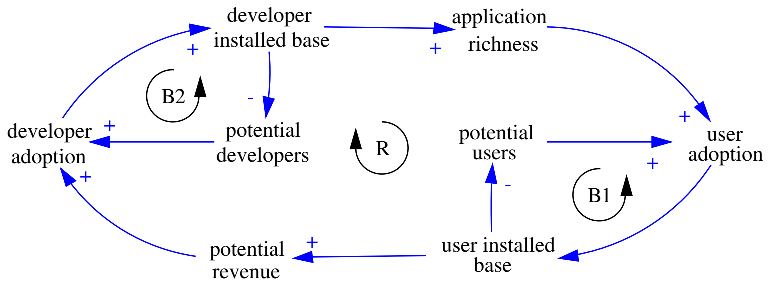


Fig. 1 Example of a causal loop diagram: network externality

potential revenue opportunities and adoption intentions for developers. On the other hand, a balancing loop indicates the market saturation effect, where the increased user adoption decreases the potential user population, which then decreases the user adoption of mobile application services.

In summary, it is necessary to consider the feedback structures within complex service systems to better understand their dynamic behaviors. The causal loop diagram allows decision makers to quickly capture and represent a service system with all its constituent components, their interactions, and consequently the feedback structures for value co-creation among network actors. By understanding the structure of a complex service system, it becomes possible to better understand the problem, explain its system behavior, and generate insights. Further, it can also provide the basis for constructing the stock and flow diagram to analyze the dynamic behaviors of complex service systems.

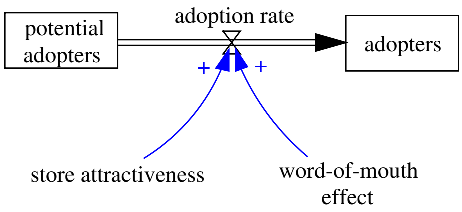
3.2 The stock and flow diagram

To model and understand the dynamic behavior of the service value network, it is required to link the feedback loop structure with stocks and flows, which are the two central concepts of dynamic systems theory. Stocks, which characterize the state of the system, are accumulations and are represented by rectangles. They generate the information upon which decisions and actions are based. For example, stocks may be the number of adopters, available applications, the number of downloads, revenues earned, capital infrastructure, etc. Inflows are represented by a pipe with an arrow pointing into (adding to) the stock. Outflows are represented by pipes pointing out of (subtracting from) the stock. Valves control the flows. Clouds represent the sources and sinks for the flows. In Fig. 2, for example, the number of adopters on an application store is increased by the adoption rate, which is the sum of adoptions resulting from word of mouth and adoptions resulting from the attractiveness of the application store (e.g., application variety).

3.3 Procedure of the service value network analysis

The proposed service value network analysis approach, based on the modeling process of SD (Sterman 2000), consists of the following six steps.

Fig. 2 Example of a stock and flow diagram



1. Define the objectives of service value network analysis
   The first step is to understand the problem and define a clear purpose that would decide the boundary of analysis to focus the study. The focal firm is required to rethink the value proposition or service offerings to its stakeholders or other network actors based on the concept of service value networks. The main challenge for the focal firm to define network objectives is it requires a holistic view of the value proposition that considers benefits and costs to other network actors. For building a successful service value network, the focal firm is required to understand not only the role of each network actor played, but also their goals which drive them to participate in the service value network. In other words, the role of a focal firm is viewed as a central actor within the service value network who is responsible to integrate the needs, objectives, and competences of other individual network actors and convert them into value offering for customers (Perks et al. 2012). Moreover, defining a clear purpose could help to decide what to include in the model and what to leave out. The rule of thumb is to include all the actors and variables as well as their relationships in the system which are considered important to explain the dynamic behavior in the analysis (Forrester 1994). The following two steps deal with this issue further.
2. Identify actors in the service value network
   Identifying actors requires the identification of all those actors having a direct or indirect influence on its value propositions toward customers. A service value network can involve several types of actors, such as suppliers, complementers, and competitors, which would affect the ability of a firm in the network to produce and deliver value to an intermediate or final customer or end-consumers. In addition, other types of actors, such as government agencies, R&D or educational institutions, financial institutions, and industry associations, can also shape and influence the performance of value networks. Note the complexity of service value network usually increases with the number of actors (Basole and Rouse 2008). Therefore, it is crucial to select the "right" actors in the service value network analysis based on the clearly determined objectives.
3. Determine the interactions among network actors
   From service-dominant logic, the process of co-creating value is driven by value-in-use, but mediatized and monitored by value-in-exchange (Lusch et al. 2008). Therefore, the value-in-use is always co-created in interactions among

individual network actors through the integration of resources and application of competences. It requires a clear understanding of exactly what kind of value is desired by each network actor. This step is to capture the perceived value-in-exchange of the different actors in regard to being part of the service value network. The e^3 value modeling tool, which has often been used to model a network of enterprises creating, distributing, and consuming things of economic value for e-service applications, is applied in this paper to capture and represent interactions among network actors (Gordijn and Akkermans 2001).

4. Develop the SD models
   After understanding the interactions among network actors, this step studies the system structure and behavior of the service value network for value co-creation. The variables that are important to exchange or co-creation of service offerings and causal influences among the variables must be identified. The causal-loop diagram can be used to recognize the interdependencies and feedback loops of the service value network that may help capture the mental models of decision makers, explain its system behavior, and generate insights for strategy development. In addition, the stock and flow diagram can be used to understand and analyze the network dynamics of the service value network. From the causal-loop diagram, the feedback loops that are crucial to influence the system behavior or performance of service value network are the focuses for building the stock and flow diagram. Variables that are dynamics of interest are considered as stocks, such as critical resources and network performance metrics, while variables that increase or decrease the levels of stocks are considered as flows.
5. Conduct model testing
   Model testing compares the simulated behavior of the model to the actual behavior of the system (Sterman 2000).The developed model is tested and validated by expert interviews or checking whether the dynamic behavior of the developed model can replicate the historical data (Forrester and Senge 1980). Other model testing methods can also be used (Barlas 1996).
6. Policy design and evaluation
   The model is used for improving the value co-creation of the entire service value network. Since the feedback structure of a service value network determines its dynamics, a new policy may involve changing the values of the parameters, feedback loops, eliminating time delays, and so on. In addition, the impact of policies and their interactions may need to be assessed.

Further, the service value network analysis is a process of discovery which is iterative in nature. The goal is to reach new understanding of how to establish a new business model or to design high leverage strategies for improvement based on the emerging concept of the service value network. What is learned from the process of network analysis may change the basic understanding of the problem and the model purpose. Therefore, iteration can occur from any step to another step. Please refer to Sterman (2000) and Forrester (1987; 1994) for more details of SD modeling guidelines.

4 Case study of Taiwan's mobile application services

4.1 The case background

A case study of Taiwan's mobile application service is used to illustrate the proposed SD approach. The development of case study is based on the prior literature (Chen and Cheng 2010; Kimbler 2010; Müller et al. 2011; Raivio and Luukkainen 2011; Hsieh and Hsieh 2013), second-hand data (FarEastone 2010; Institute of Information Industry 2011; VisionMobile 2013), and interviews with industrial experts. The important factors for user attractiveness were collected from interviews from six senior managers, each with more than 10 years working experience in the mobile telecommunication industry (one manager) and the software/content industries (five managers). The case background is described as follows.

Due to subscriber growth saturation and voice tariff competition, Taiwan's mobile operators have had declining ARPU in the past few years. Therefore, mobile operators began to innovate with value-added services (VAS) that were expected to create value for end-consumers and thus lead to continued growth. Since 2005, several mobile operators have launched their own mobile content services based on the operator-centric model and dominated the distribution of mobile contents and services. However, due to the lack of attractive content and software integration support, revenue from the mobile content value-added services was less than 10 % of ARPU in 2008 (Chen and Cheng 2010).

Since its launch 2008, Apple's App Store has redefined the way consumers use the mobile Internet. Taiwan's three major mobile operators, Far EasTone Telecom, Chunghwa Telecom, and Taiwan Mobile, began copying the App Store model by building their own online marketplaces, namely: S Marketplace, Hami Apps, and Match Market, respectively. Far EasTone's S Marketplace began to provide services in late 2009, and the other two in mid-2010 (see Table 1). According to the 2011 survey from the Institute of Information Industry, 32 % of Taiwan's mobile internet users have downloaded applications, and 86 % of these have downloaded in the past month (Institute of Information Industry 2011). Nearly 60 % of the consumers downloaded free software. Compared to other Asian countries, Taiwan mobile internet users are more willing to pay for mobile applications from application stores. However, the average payment amount is the lowest in all of Asia, only US $1.67.

The industrial survey also found Taiwan smartphone users increased by 112 % in 2011 over 2010 ($\sim$290 million). In addition to the future growth potential of new users, 48 % of smartphone users will use more applications. This shows Taiwan mobile internet users have gradually adopted mobile application services. It is expected this market will continue to increase in the future and will become an important source of revenue for the three mobile operators. However, the challenge still remains for mobile operators to develop an appropriate strategy or a business model to increase their application stores' market share and achieve revenue growth.

Table 1 Three mobile application stores developed by Taiwan's major mobile operators

App stores	Launch date	Carrier	Number of applications[a]	Number of downloads	Platform	Personal publishing	Revenue sharing (%)
Hami Apps	2010.5.27	Chunghwa Telecom	1,300	0.5 M	Android	Yes	70
Match Market	2010.4.26	Taiwan Mobile	600	Unknown	Windows, Android, Blackberry	Yes	70
S marketplace	2009.10	Far EasTone	1,500	1 M	Android	Yes	70

[a] The number of apps: http://3c.msn.com.tw/View.aspx?ArticleID=56172&pageIndex=3

4.2 Defining the objectives of service value network

This research assumes the focal firm in the mobile application service value network is a mobile operator (Company 1) who had anticipated the rise of the app economy and launched the first application store in Taiwan. However, other mobile operators also moved into the market a few months later, and one of them even has significant resources in terms of greater brand equity and a larger installed base of mobile communication service users. Due to the strong competition from mobile device manufacturers (e.g., Apple and Google) and other mobile operators, it is challenging to grow market share in Taiwan's mobile application market. The company understood it was not possible to compete with application stores operated by mobile device manufacturers at the current stage. However, since many developers or users are multi-homers who publish their applications on multiple application stores or download desired applications from different application stores, it is still possible to persuade developers or users to add another "home base," rather than switch from the application stores managed by mobile device manufacturers.

Company 1 aimed to develop adequate service value network strategies for promoting its mobile application services and then grow its market share in Taiwan's mobile application market relative to Taiwan's other mobile operators. The company intended to enhance the volume and variety of applications by attracting more service adoption from developers to increase the volume of user adoption. Moreover, since the purpose of the SD model is to help a mobile operator determine suitable strategies for improving their market share relative to other Taiwan's mobile operator and all mobile operators have to face the strong competition from device manufacturers; competition from device manufacturers is not included in the analysis.

4.3 Identifying actors in the service value network

According to Müller et al. (2011), the mobile application service ecosystem may involve the following actors: end user, network operator, payment broker, advertisement broker, app store service provider, operating system developer, device manufacturer, application developers, etc. For illustrative purpose, this research only considers three key actors to reduce the model complexity, including service providers, application developers, and end-users. Other network actors also can be included as needed.

4.4 Determining interactions among network actors

The interactions among application store service providers, end-users, and developers are represented in Fig. 3, according to the e^3 value modeling notation standard (Gordijn and Akkermans 2001). Application stores allow users to search, buy, and download applications for enhancing the functionality of their mobile devices. The value-in-exchanges involve money and user information in exchange for desired applications and services provided by the application store. On the other side, software developers develop, promote, and sell their applications to users

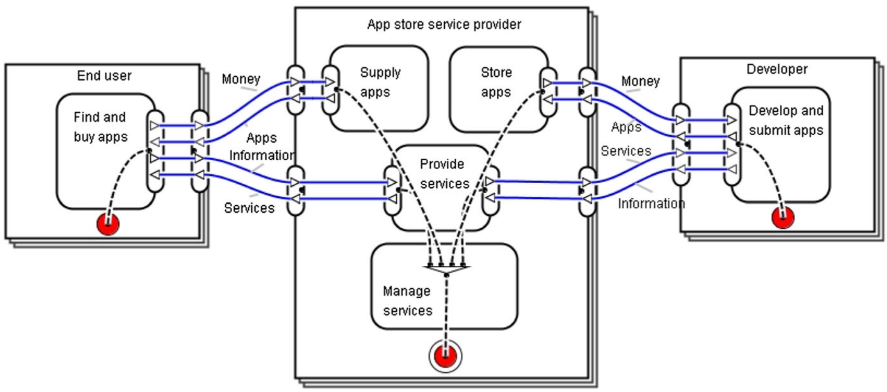


Fig. 3 Interactions between key network actors

through the application store. The value-in-exchanges involve applications and money (e.g., commission and registration fee) in exchange for services, such as toolkits, documentation, and support, etc.

In addition to the explicit interactions among networks, the application store service provider also needs to consider network externality that is the key feature of the mobile application services ecosystem for improving their business performance (Holzer and Ondrus 2010; Rao and Jimenez 2011). The concept of network externality, or the network effect, was developed by Katz and Shapiro (1985), in which the value of a good to a user increases with the user base of the compatible products. It has been applied in various markets; for example, CD/DVD players, software, video game consoles, mobile/smart phones, etc.

The network externality in the mobile application market is more complicated, because benefits on one side of the market increase with the number (and/or quality) of participants on the other side (Holzer and Ondrus 2010). On the developer side, adding another developer producing similar applications will increase competition among developers, weakening the network effect on one side of the market. However, buyers in the consumer market welcome the entry of competing developers, because this can increase application variety, while possibly lowering prices. Therefore, the externality arises from developers to end-consumers.

On the end-consumer side, consumers care less about adding another consumer to the application store, and they are more concerned about the number of applications and the diversity of applications delivered by developers on the application store. However, developers care greatly about the size of the consumer market because a larger consumer base has higher potential market size for future revenue growth. Therefore, the externality propagates across markets from consumers to developers. Though it has been reported the free download volume is at least 10 times higher than the paid volume, developers can still monetize their users by advertisements or a premium offering with in-app payments.

In summary, mobile operators are required to capture interactions and network externalities among network actors for better understanding the system structure of their mobile application services for value co-creation. The SD approach is used in the next step to model and evaluate the feedback structures and dynamic behavior of mobile application services.

4.5 Developing the SD model

4.5.1 Causal loop diagram for mobile application services

After considering the interactions among network actors and network externality of the mobile application services, a conceptual formulation of the feedback structure for mobile application services is developed and depicted in Fig. 4. This can help decision makers understand the system structure of mobile application services more deeply.

The user adoption rate of mobile application services results from word-of-mouth effects and the attractiveness of application prices, application richness, and service quality. A large user base will lead to stronger customer acceptance via the word-of-mouth (WOM) effect, forming positive customer dynamics loop R1. Since free applications are commonly available for customers to download as they wish, customers in the application store market are very price sensitive (West and Mace 2010). In other words, the higher the application price, the lower the adoption rate, which will reduce the adoption population and paid download rates, while reducing market share and revenue. As the number of downloads or market share is misaligned with the target, developers may cut application prices or mobile operators may promote price reductions or even free applications (e.g., "free app of the week") to attract user trials and downloads. A higher adoption rate increases market share, while enhancing the revenue of the firm, forming negative pricing dynamics loop B1.

Application richness is a major value proposition for the application store business model (Kimbler 2010). Higher application richness will increase the user adoption rate and population size, leading to higher download rates and revenue for application store service providers. As download rates grow, developers will receive higher revenue through their predetermined revenue sharing agreements with the mobile application service provider, encouraging developers to join and contribute more applications to the application store, forming positive application richness loop R2.

In addition to providing the necessary connectivity to transport applications to customers, realizing service quality is a crucial factor for a mobile operator to enter the mobile application market (Gonçalves 2010). The mobile application store allows users to search, browse, and download applications from the store. It also provides services for developers to upload, edit, approval, and publish their applications. Enhanced service quality will increase the user adoption rate and developer production rate, leading to increased revenue for the firm. This revenue growth encourages the mobile operator to continuously invest in its own service infrastructures, including hardware and software (e.g., uptime, response time, download speed, development toolkits), as well as recruiting and training engineering and service staff (to handle exceptions, problems, complaints, hacker

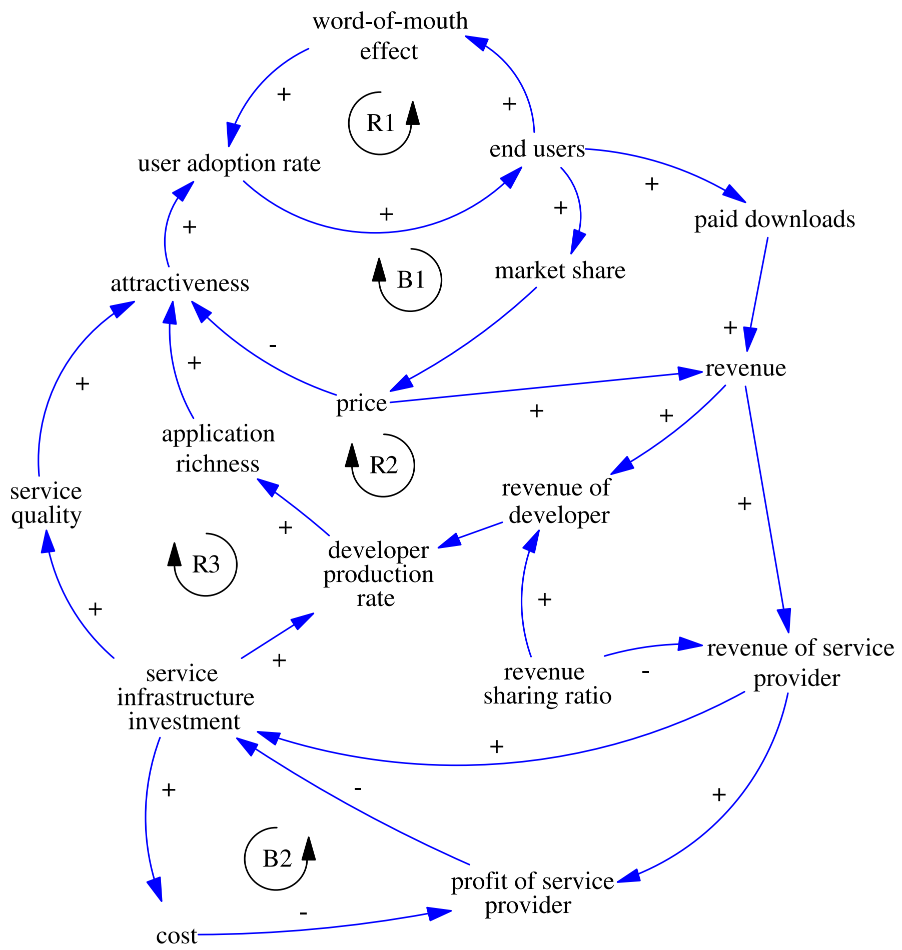


Fig. 4 Causal-loop diagram for the mobile application service

attacks, etc.). This results in further service quality improvement, forming positive service quality dynamics loop R3. However, increased infrastructure investment will also lead to reduced profit for the mobile operator, forming negative infrastructure investment loop B2.

4.5.2 Stock and flow diagram for mobile application services

From the causal-loop diagram shown in Fig. 4, we recognize four dynamic forces driving the system behavior of mobile application services: customer dynamics, pricing dynamics, application richness dynamics, and service quality dynamics. We further elaborate each dynamic force with the stock and flows diagram to clarify the knowledge and understanding of their system structures and dynamic behaviors.

The customer dynamics model is adapted from the Bass diffusion of innovation model (Bass 1969; Mahajan et al. 1995), where the user adoption behavior is determined by the process of how new products or services are adopted as an interaction between adopters and potential users. Since only 3G users can download and use applications from application stores, this paper assumes all potential users are 3G users. The structure of the customer dynamics model, as shown in Fig. 5, focuses on the adoption flow between the stock of 3G users and the stock of service adopters. The adoption rate of the application store is mainly determined by its overall attractiveness due to application richness, prices, service quality, word of mouth, and the time required for new 3G users to become comfortable with the application store. The greater the overall attractiveness of the application store, the more rapidly potential users will adopt it. The word of mouth effect influences 3G users to use mobile applications from active adopters and this effect is determined by the adoption fraction and the contact rate. Meanwhile, some adopters who are not satisfied with the application store in use, may leave the store, and this churn rate is the inverse function of the overall attractiveness effect of the application store (Karikoski et al. 2009). In addition, the model considers each adopter as able to repeatedly purchase applications from the application store.

The increase in 3G users is determined as the rate of 2G users moving to 3G services. According to data from the National Communication Commission of the Ministry of Economic Affairs, the total number of mobile phone users was approximately about 27.43 million in June 2011, 70 % of which were 3G users, and with a switching fraction of about 2.1 % per month. The adoption fraction and contact rate for the word-of-mouth effect are set to 0.15 and 100 per month, according to Wang and Cheong (2006).

The pricing dynamics model is developed based on Sterman et al. (2007) to emulate the price dynamics and its attractiveness to consumers' adoption decisions, as shown in Fig. 6. With lower prices, there is a higher attractiveness level. Since competition is becoming increasingly intense and consumers can easily find free applications from application stores, the average price of applications across all application stores has continued to decline in recent years. In the mobile application business, the pricing decision of an application is mainly determined by the developers based on the rules provided by the service provider. From the developer perspective, we assume the cost-orientation method is used and a developer has an expected price to sell a developed application to make the most profit per copy sold. However, the developer does not know the exact price that consumers are willing to pay, where the expected price equals the unit application cost plus the normal profit margin desired by developers. As the adopter population size increases in the application store, the expected number of downloads will increase, leading to decreased unit application cost.

Moreover, when sales are below the target market share, mobile operators will launch promotion activities with developers to enhance adopters' purchasing intentions for improving their market share. A larger target market share gap causes a higher discount rate, resulting in lower prices to increase consumers' purchasing intention. Therefore, the target price is influenced by the net effect of the

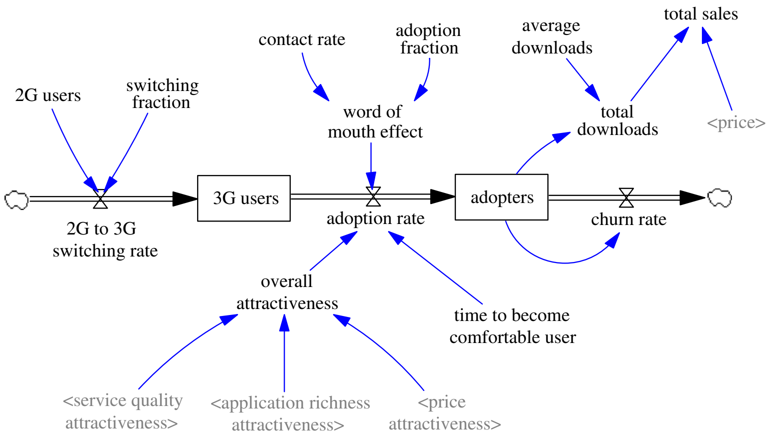


Fig. 5 Customer dynamics subsystem

developer's expected price and the discount rate of the mobile operator, where the unit application cost is used as its lower bound.

Finally, the change in the application price is determined by its target price and price adjustment time (0.25 month). The attractiveness of the perceived price is determined by the ratio of the price and the maximal user acceptable price which is the maximum application price on the application store (NT $890), where the smaller the ratio value, the higher the attractiveness of the perceived price.

The application richness dynamics model (Fig. 7) simulates the dynamic behavior of the application richness of the application store which attracts consumers to adopt mobile application services. In addition to the initial applications gathered by the mobile operator, new applications will accumulate over time and existing applications will be outdated and become obsolete over time within the application store. The application production rate is determined by the average growth rate, adjusted by three important factors, namely, the attractiveness of total sales, service quality of the application store to developers, and the effort by the mobile operator to reach the target application size.

One of the important factors influencing the application production rate is the willingness of developers to contribute their applications to the application store. According to the literature (Holzer and Ondrus 2010; Hsieh and Hsieh 2013), developers are more willing to develop applications for an application store that has a larger installed base and better service quality (e.g., quick review process, easy to use toolkit, etc.). Therefore, this paper assumes the production rate is influenced by the attractiveness of the total sales of the application store to developers and its service quality. Another factor influencing the production rate is the mobile operator's effort to reach the target application size in the application store. To enhance its market share, mobile operators have started to collaborate with third parties to develop applications that are more appropriate to local market requirements (e.g., mobile media entertainment, mobile GPS, and health-care services).

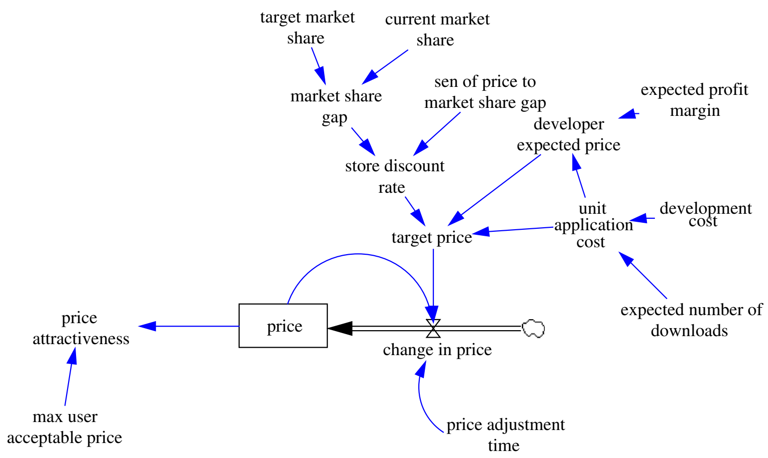


Fig. 6 Pricing dynamics subsystem

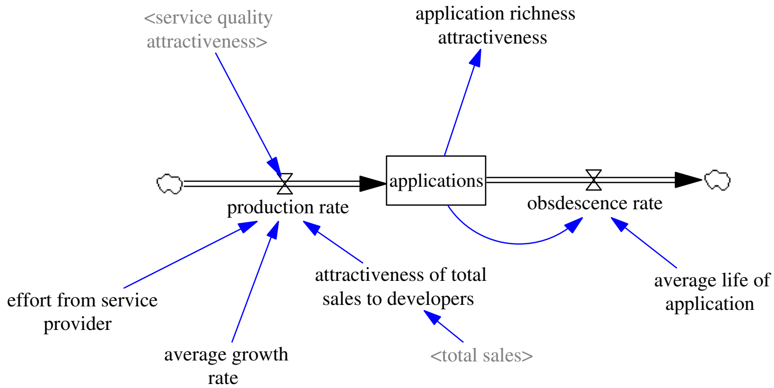


Fig. 7 Application richness dynamics subsystem

In this study, the average growth rate of different mobile operators was from 2009/04 to 2011/07. The application size of the application store was initially set to the available applications on the FarEastone S Mart in early December 2009 and the target amount of applications was set according to the target amount for 2013 announced by FarEastone (2010). The application obsolescence rate was determined by the current application size and the average life of the application.

The service quality dynamics model is shown in Fig. 8. This model was developed based on an online bookstore service quality model by Oliva et al. (2003) to assess the service attractiveness to users and developers, according to the rates of service infrastructure investment and infrastructure depreciation. The application store service infrastructure is considered as a stock, where the amount of infrastructure investment depends on the initial service infrastructure, an increase in investment per period, and a depreciation of infrastructure per period. After the initial investment in the service infrastructure, the mobile operator would increase investment in new infrastructure over time to meet the requirements for developers and users. The amount of new service infrastructure investment is determined by the gap between the required and current capacities of service infrastructure, where the required capacity is based on the numbers of adopters and applications on the application store multiplied by the unit investment based on Oliva et al. (2003). The new investment becomes effective depending on infrastructure adjustment time (3 months).

The attractiveness of service quality is determined by the service performance perceived by users and developers. The adequacy of the service infrastructure is the ratio of the current service level and required service level of the service infrastructure. The more it can meet the required service level, the greater the service adequacy is. In addition, it usually takes some time (customer memory) for users and developers to adjust their perceptions toward the upgraded application store performance.

4.6 Conducting model test

The base case simulation involves competition between two major telecommunication operators in Taiwan which have anticipated the rise of the app economy. Company 1 entered the market at the end of 2009 and Company 2 moved into the market 5 months later, but with significant resources in terms of greater brand equity and a larger installed base of mobile communication service users. Table 2 summarizes the initial conditions for the base case simulation. We assume both companies adopted an aggressive strategy to penetrate the mobile application service market. Thus, the target market share was set to 80 % for both companies.

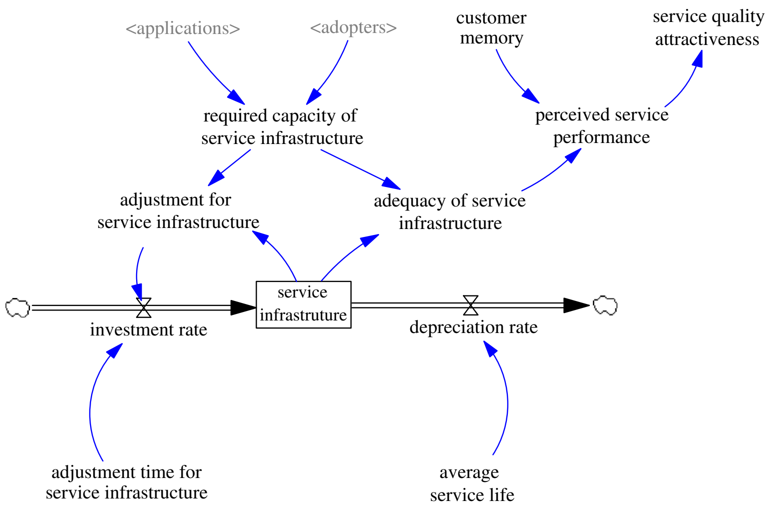


Fig. 8 Service quality dynamics subsystem

Table 2 Parameter settings for the base case simulation

Initial average price of apps[a]	NT$ 74
Initial investment on the service platform[b]	NT$ 1.45 M
The initial number of apps on the service platform	100
Profit margin for developers[c]	30 %
Target market share	80 %
Revenue-sharing ratio	70 %
Unit investment on the platform	NT$ 124.7

[a] AdMob mobile metrics report (2010): http://www.google.com/ads/admob/

[b] According to Oliva et al. (2003)

[c] According to the report by Asymco Co.: http://www.asymco.com/

Since neither company revealed their investment data, the initial investment amount in the application store was based on the investment data for an online book store by Oliva et al. (2003). According to the official announcement by company 1, the initial number and the target number of applications at the end of 2011 on the application store were set to 100 and 3,000, respectively. The initial average application price was set to NT$74 (US$ 2.47), according to the survey report by AdMob, which is a leading mobile advertising company (AdMob 2010).

The base case simulation was calibrated to match the growth patterns of the adopters and applications for the application store provided by Company 1. According to the data collected from Company 1, the adopter population grew to 0.26 million from Dec 2009 to Apr 2011. The number of applications in the application store increased from hundreds to over two thousand within 18 months. By observing the simulated curve, the pattern of adopter population size appears to have a trend similar to the actual curve of the adopter population size from Dec 2009 to Apr 2011 (see Fig. 9). Similarly, a comparison of the actual and simulated numbers of applications shows they are close to each other (see Fig. 10). These results demonstrate the validity of the developed SD model.

Figure 11 extends the base-case simulation over 3 years. From Fig. 11a, b, it appears that Company 1 dominated the entire market for the 3-year period. Though Company 2 applied an aggressive strategy with lower application prices to penetrate the market, Company 1 quickly had similar price cuts to maintain its market (Fig. 12c). Moreover, since Company 1 entered the market 5 months earlier than Company 2, it had the first-mover advantage (Lieberman and Montgomery 1988). Thus, Company 1 had more applications and adopters, as well as a higher level of service infrastructure investment than Company 2 (Fig. 12a, b, d), leading to higher revenue and market share for Company 1.

These results indicate Company 1 had a strong first-mover advantage and it was not easy for a fast follower, Company 2, to catch up with the leading company. To respond to the new entrant, Company 1 applied the right strategy to attract customer concern and loyalty by quickly reducing the price to attract users to its application store, while increasing the service infrastructure investment for enhancing service quality (Lieberman and Montgomery 1998). A first mover is also able to select an

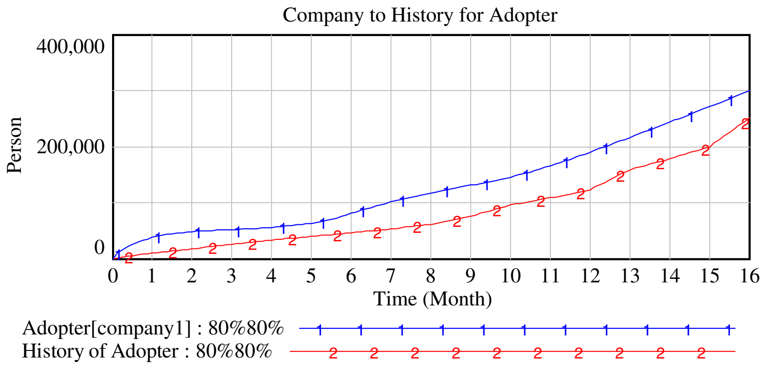


Fig. 9 The number of adopters: the simulated and actual curves

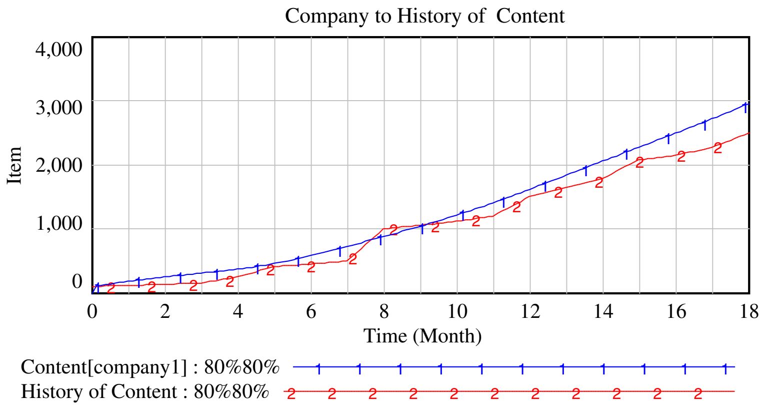


Fig. 10 The number of applications: the simulated and actual curves

attractive position in the market, so a fast-follower is unable to obtain competitive advantages.

4.7 Policy design and analysis

To assess the limit of the first-mover advantages (Fernandez and Usero 2007), we use the developed SD model to explore related issues that may cause Company 1 to lose its advantage. The first issue that may influence the application richness is the revenue-sharing ratio. In the mobile application industry, developers sell their applications on application stores provided by mobile operators and the revenue from selling applications is divided between developers and mobile operators. A higher revenue-sharing ratio that increases the unit profit of a developer, may attract more developers to contribute their applications to the application store and thereby improve the application richness of the application store. Before Apple launched its own App Store, the revenue-sharing ratio ranged from 60 to 80 % (Peppard and

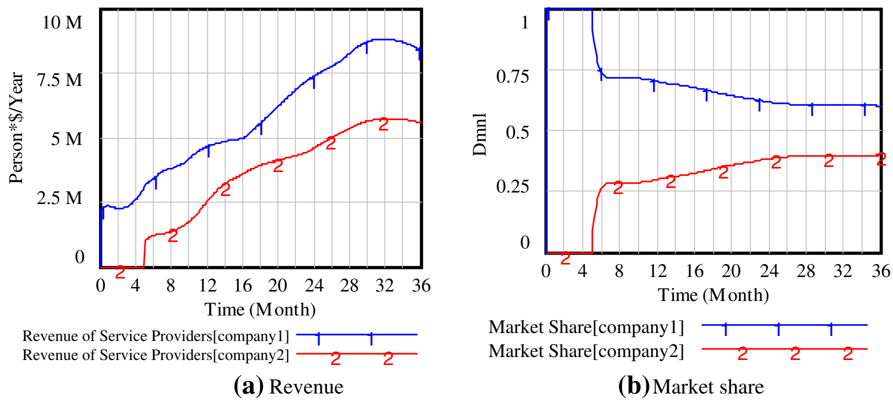


Fig. 11 Results of base model simulation: **a** revenues and **b** market shares

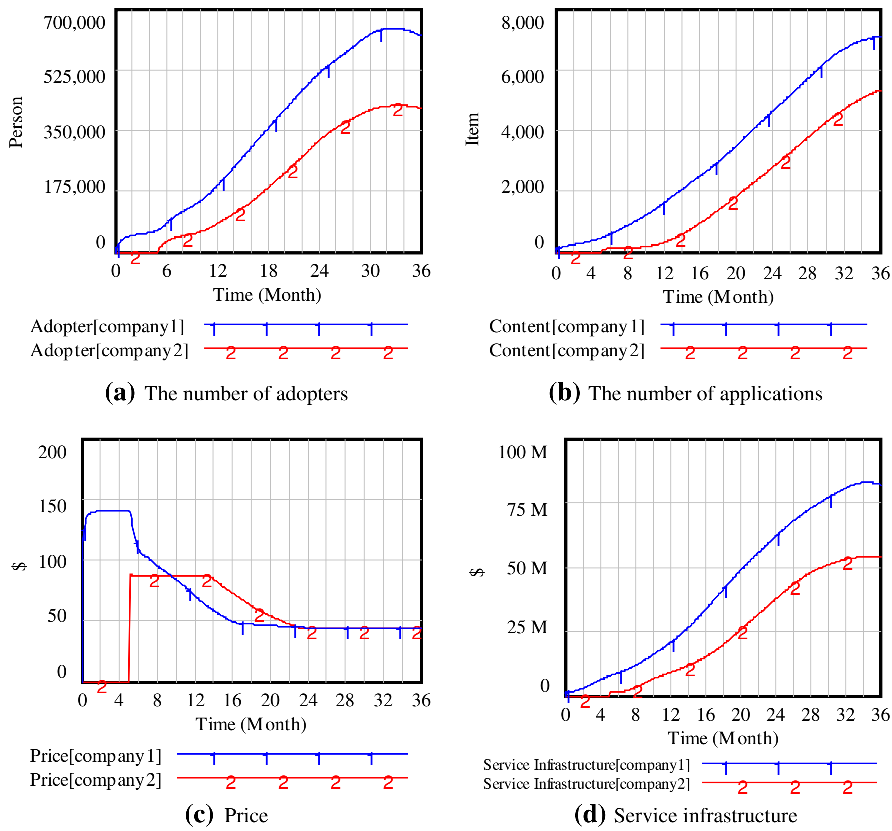


Fig. 12 Results of base model simulation

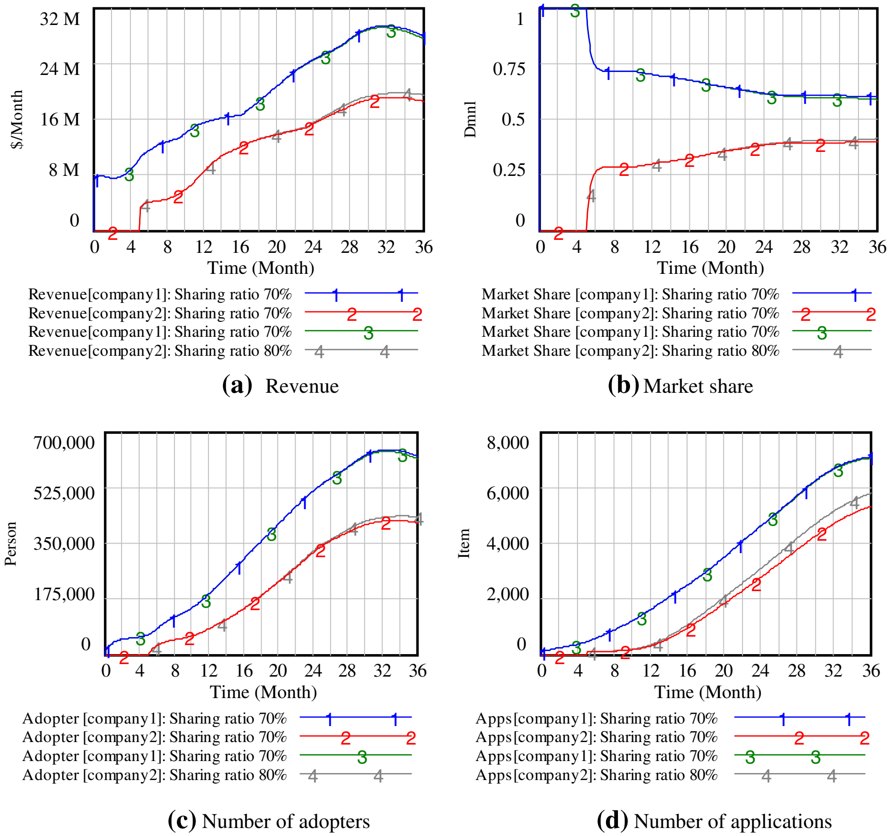


Fig. 13 Results of the higher revenue-sharing strategy

Rylander 2006). Now, almost all application store service providers set their revenue-sharing ratio at 70 %.

Similarly, all Taiwanese mobile operators have currently adopted the same revenue-sharing ratio and so we consider if an even higher revenue-sharing ratio can help a fast follower capture market share. We assume Company 1 kept the revenue-sharing ratio unchanged, while Company 2 varied its revenue-sharing ratio from 70 to 80 %.

Figure 13a, b shows that Company 1 still dominated the market over 3 years. Although, in addition to the increased adopters and applications (Fig. 13c, d), the market share of Company 2 increased slightly (curve 4 in Fig. 13b), but it did not have a significant impact on Company 1. This result indicates the fast-follower cannot increase its market share significantly through higher revenue-sharing ratios.

The second issue is whether the fast follower can capture higher market share by increasing its own service infrastructure investment. We assume Company 2 increases its investment in the service infrastructure by 10 or 20 % of the original amount to improve its service quality to attract more users or developers to adopt its

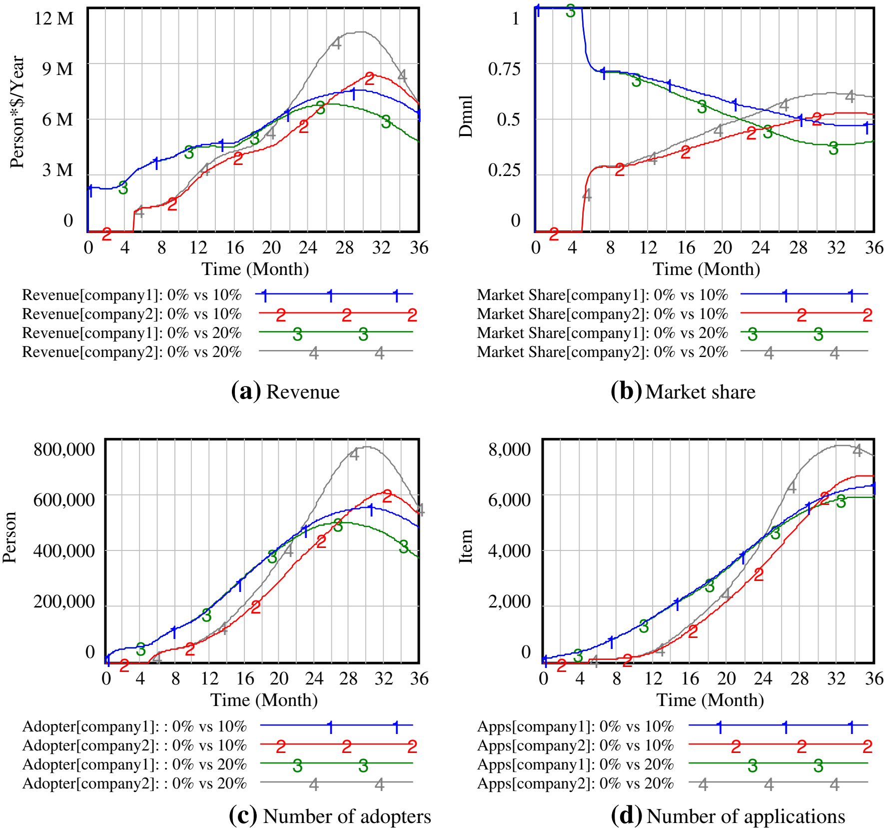


Fig. 14 Results of the service quality improvement strategy

application store, while the first mover, Company 1, keeps its infrastructure investment unchanged.

Figure 14 shows, through the additional amount of infrastructure investment in the application store, Company 2 can gradually improve its user population size, application richness, revenue, and market share. The market share of Company 2 exceeds that of Company 1 at the 28th (22th) month with 10 % (20 %) additional unit infrastructure investment. An improved service quality of the application store (e.g., efficient review process, better development toolkits) will attract more developers to develop applications for the application store, leading to increased application size and better application richness. Better service quality and application richness will attract more end-users to adopt the application store services and increase the number of downloads, which in turn, increases the revenue and market share of the mobile operator. Though Company 1 has the first-mover advantage, it will gradually lose its market share if it keeps unit infrastructure investment unchanged. In addition, to maintain its market share, Company 1 will be forced to lower the application price, which will in turn reduce revenue and lead to less money available for further investment to improve service quality.

These results show enhancing service infrastructure investment is an appropriate strategy for a mobile operator because it can improve overall service quality, forming positive feedback loops for the application store ecosystem and thus increasing market share and revenue growth. Therefore, the first mover also needs to sense their competitors' movement and quickly respond to continuously enhance their own infrastructure investment for sustainable growth.

5 Conclusions

Since the complexity and scale of service has become larger than before, service innovation has become a major challenge for many organizations. It is required to manage complex services from the system perspective. This paper developed a SD approach for analyzing the system structure and dynamic behavior of service value networks. A case study of Taiwan's mobile application services was used to illustrate the developed methodology.

We can find several benefits of using the SD approach from the case study. First, SD models provide a higher level view of the entire service system, focusing on co-creating customer values and managerial policies. They have an inherent flexibility to incorporate a wide range of influences specific to service systems; e.g., influences from mobile device manufacturers. Second, the SD model can represent feedback processes, which are inherent in the complex service system, for better supporting decision making for value co-creation. Third, SD simulation models provide a laboratory to test several different scenarios for the system, delivering a clearer view of the possible futures for better policy design and evaluation. Based on the obtained results, we recommended the case company should sense the market development of mobile application services continuously and improve its service quality on both sides of users and developers relentlessly for sustaining its market growth.

Since the mobile application service market is a complicated ecosystem, future research can include other network actors in the service value network analysis; such as, advertisers or device manufacturers. How to compete with application stores run by device manufacturers is a very important issue worthy of further investigation for mobile operators.

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