Systems Evaluation for Business Sustainability and its Application to Regional Air Transportation

September 2013

Nobuaki MINATO

(Intentionally Blank)

Executive Summary

A business is not intrinsically self-sustainable. According to the statistics of the Ministry of Economy, Technology and Industry (METI), 73.9% of newly established enterprises disappear within 10 years (Li, 2011). For the purpose of acquiring sustainability in a competitive market, we need to appropriately monitor, evaluate, and manage typical behaviours of business systems such as growth, oscillation and decay overtime. But such methodology for evaluating business systems is not well-established yet. Therefore, the purpose of the thesis is to propose an integrated methodology to evaluate sustainability of business systems and apply it for transforming unsustainable regional air transportation to be a more self-sustained system.

Previous researches on sustainability evaluation tend mainly to discuss the intersection of the triple bottom line of environment, economy and society. However, the approach has been ossified and lacks the capability of evaluating dynamics within business systems. It ignores dynamic interactions of business stakeholders which continuously changes balances of benefits and risks during business lifecycle. Thus, the thesis decomposes business systems evaluation into three stages; growth, maturity and decay, and identified issues associated with each stage. I proposed an integrated systems evaluation framework which can evaluate business systems from three perspectives; Scalability, Stability and Durability. Systems evaluation technologies such as mathematical modelling and simulation modelling are integrally applied in the framework.

The thesis comprises 5 parts and 11 chapters. Part 1 (Chapter 1 to Chapter 3), Issue and Theory, provides the problem definition and theoretical framework. In Chapter 1, Introduction, the research background, motives, problem, purpose, and questions are illustrated. In Chapter 2, Sustainability and Air Transportation, I discussed the definition of sustainability concept and its limitations. I also review the extant researches on business systems evaluation, allowing me to highlight the originality of the thesis. In Chapter 3, Systems Evaluation Framework was introduced with associated evaluation technologies.

Part 2 (Chapter 4 and Chapter 5) addresses “Stability of Business Systems.” In Chapter 4, Airline - Airport (Multiple Airways), I introduced a mathematical portfolio modelling based on financial engineering to look at ways to reduce business risks of demand fluctuation by diversification using air traffic data to remote islands. In Chapter 5, Airline – Airport (Single Airway), I developed a quantitative, dynamic simulation model of load factor guarantee using System Dynamics for evaluating risk sharing mechanism among the stakeholders. The Haneda-Noto flight data was utilized for examination.

Part 3 (Chapter 6 and Chapter 7) addresses “Durability of Business Systems.” In Chapter 6, Air Transportation Ecosystem, I introduced an ecosystem modelling of regional air transport community using System Dynamics, aiming at balancing stakeholder’s benefits and risks when business systems are decaying overtime. In Chapter 7, Air Transportation and Disaster, I discussed the substitutability of regional air transportation under catastrophic natural disasters analysing the case of the 2011 East Japan Great Earthquake and Tsunami. An effective management model under catastrophe was illustrated and a new added value of underutilized regional airport was highlighted.

Part 4 (Chapter 8 through Chapter 10) addresses “Scalability of Business Systems.” In Chapter 8, Systems Evaluation on Competitiveness, I proposed a matrix operation model for a trade analysis to systematically evaluate competitiveness of business systems from technical, market and social perspectives. In Chapter 9, Systems Evaluation on Uncertainty, I presented a Monte Carlo simulation model for evaluating business uncertainty associated with emerging technology. In Chapter 10, Systems Evaluation on Business Integration, I developed System Dynamic simulation model for assessing the degree of business system integration. In Part 5, I concluded the discussions and presented the limitations and the future works.

The primal achievement of the thesis is the integrated systems evaluation methodology for designing more self-sustaining business systems where business stakeholders symbiotically coexist in a market rather than competing with each other or being parasitic on public assistance. Furthermore, I found the fact from the quantitative simulation results that, instead of subsidizing unprofitable regional airlines or local residents as taxpayers, subsidizing ticket prices of inbound air passengers better aids the viability of the regional air transport ecosystem, primarily through the multiplier effects of attracting more passengers and the economic spillover effects.

I highlighted regional air transportation as a major example of unsustainable business systems but I think that the proposed methodology can be applicable to other business systems evaluation as well. I believe that, for instance, the methodology can be applied for public service design as business systems, which in turn, greatly contributes to future design of the country where depopulation and aging society are becoming of great issue.

(Intentionally Blank)

Acknowledgement

Through my studies and working experience in Toulouse, France, the issue of regional air transportation has gained an increasing amount of my attention, allowing me to select a research topic for my doctoral thesis without a second thought. However, this research would not have been possible without the enduring support of several people.

First, I would like to express my gratitude to Prof. Masaru Nakano of Keio University Graduate School of System Design and Management (Keio SDM) for his tremendous efforts in finalizing my doctoral thesis. Furthermore, I am grateful to my colleagues at Keio SDM, Dean Prof. Takashi Maeno, former Dean Prof. Yoshiaki Ohkami, Prof. Taketoshi Hibiya, Prof. Prof. Hidekazu Nishimura, Prof. Shinichiro Haruyama, Prof. Kenichi Takano, Prof. Naohiko Kohtake and all other professors, staffs and students for understanding and supporting my research activities at Keio University. The holistic viewpoint and systematic thinking methodology strongly inspired my introduction of the concept of ‘symbiosis’ to air transportation system design.

Most of my doctoral research activities were conducted under the Ecole Superieure de Commerce de Toulouse (ESCT). Hence, I would like to express my greatest thankfullness to Prof. Risako Morimoto of University of London (former professor at ESCT). She provided me with the opportunity to conduct doctoral research in France and continuously supported me with solid advice throughout. Without her tremendous efforts in educating me and guiding my research, I would not have been able to accomplish the project. I also would like to thank Prof. Jonathan Winterton and Prof. Jacques Tounault for coordinating my doctoral research at the ESCT. I am also grateful to Prof. Sveinn Gudmundsson and Prof Anne Vanhems of ESCT for their encouraging feedback and valuable comments during inspiring discussions.

I also would like to show my thankfulness to Prof. Kenichi Ozawa of Rikkyo University for inspiring me to evaluate tourism perspective on regional air transportation. Without his continuous encouragement, I cannot imagine the accomplishment of my doctoral degree.

My gratitude is also extended to my ex-colleagues at Avion de Transport Regional (ATR), especially to Othman Choui, Mario Formica, and Gianni Tritto, for helping me with their deep knowledge of and insights into the regional air transport business. Without my research experience at ATR, this work would not have been possible.

I would like to express my gratitude to Japan's air transport regulators, industry, research institutes, and community, as well as the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), the Tokyo Regional Civil Aviation Bureau (TCAB), All Nippon Airways (ANA), Japan Airline (JAL), Noto Airport, Ishikawa Prefectural government, Sendai Airport, Miyagi Prefectural government, Yamagata Airport, Yamagata Prefectural government, Fukushima Airport, Fukushima Prefectural government, Mitsubishi Heavy Industry (MHI), Japan Aerospace Exploration Agency (JAXA), and the Institution for Transport Policy Studies (ITPS) among many others for their supportive provision of interview opportunities and valuable data for analysis. Their cooperation greatly enhanced the quality of my research.

Finally, I owe my biggest thanks to my parents, who always supported and encouraged me throughout my studies. I cannot imagine where I would be today without their education and everlasting trust.

August 10th, 2013

Nobuaki Minato

Table of Contents

(Intentionally Blank)

List of Figures

List of Tables

List of Appendix

(Intentionally Blank)

PART 1

Issue and Theory

(Intentionally Blank)

Chapter 1. Introduction

Chapter 1 provides an overview of my doctoral research. It is divided into six sections. The section 1.1 describes the background of the research. The section 1.2 explains the research motivation. The section 1.3 defines the purpose and the target of the research. The section 1.4 analyses the problems in the research. The section 1.5 explains the research strategy. Finally, the section 1.6 explains the structure of my doctoral thesis.

1.1. Research background

1.1.1. Growth and Decay of Air Transportation

The history of modern aviation started in 1903 when the Wright Brothers, Wilbur and Oliver, succeeded in flying an airplane in Kitty Hawk, North Carolina, U.S.A. Only three years later (1906) the first European flight was accomplished in France by Alberto Santos-Demont (Inoue, pp. 5, 2008). Japan’s first flight occurred seven years after the world’s, when two Japanese military officers, Lieutenants Tokugawa and Hino, flew an airplane for the first time in Tokyo, Japan, on December 19, 1910 (Inoue, pp. 3-12, 2008). This was the dawn of Japanese aviation history.

One hundred years have passed since the first flight. The air transportation in Japan has experienced both drastic growth and decay of the market. According to Ministry of Land, Infrastructure, Transport and Tourism (MLIT), the air traffic has continuously increased during the 20th century and reached its maximum of 114,553,351 passengers in 2002 (Fig. 1.1). In the beginning of the 21st century, on the contrary, the market was saturated and thereafter drastic decrease began (Fig. 1.1). There were recessions after the events such as the 9.11 attack in 2011 and Lehman shock in 2008 but demand for air transport has proved robust in the face of such repeated shocks (Pearce, 2012). Today, 79,052,000 Japanese are travelling on Japan’s domestic airways, and 12,594,000 are flying internationally (Air Transport Statistics 2012, MLIT).

The initial rapid and continuous growth of air traffic (see Fig. 1.1) has been strategically designed and controlled by the Japanese central government (Ohta, 1999). Many airports have been constructed across the country since the 1950s according to the Airport Development Plan, based on the Airport Development Law (Mita et al., pp. 109-139, 2010). Airlines have been regulated by the Ministry of Transport (MOT) under a management structure called the ‘45/47 framework’. Japan’s air transport system has been strongly protected and regulated for years.

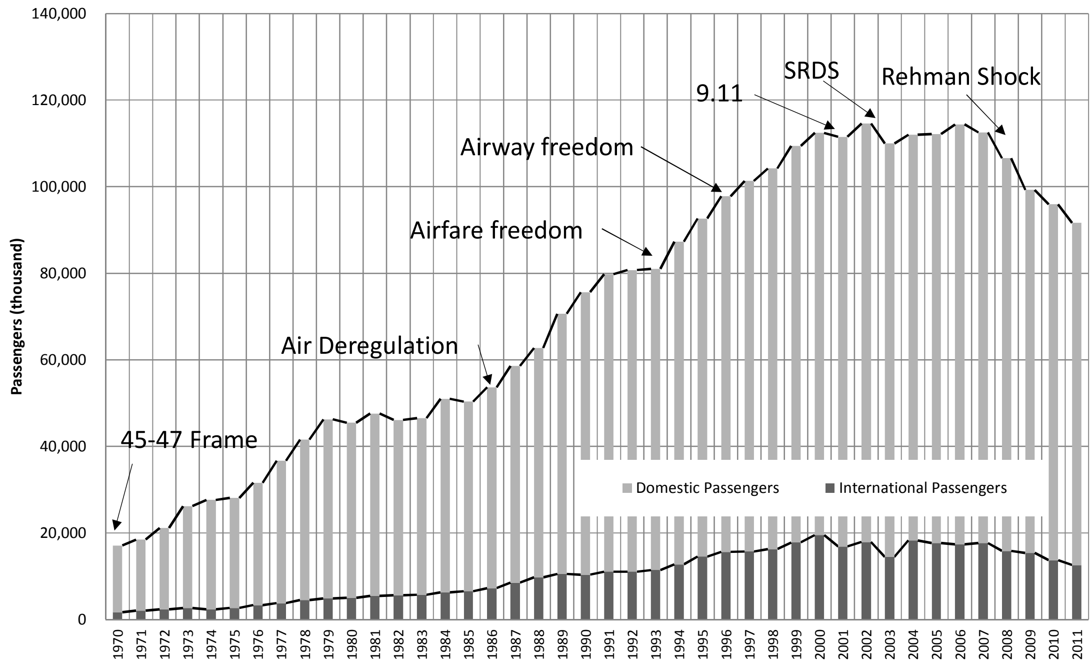


Fig. 1.1 Air Passengers in Japan (MLIT, 1970-2011)

The 45/47 framework was an administrative policy that allocated specific roles to the major Japanese airlines. It was authorized by the Cabinet Council in 1970 (Showa 45 in the Japanese dating system) and implemented by the Ministry of Transport in 1972 (Showa 47 in the Japanese dating system) as the '45/47 framework'. Under the framework, Japan Airline (JAL) was allowed to operate international and domestic mainline flights. All Nippon Airways (ANA) was allocated domestic mainline and domestic local flights. Japan Air System (JAS) was allocated domestic local flights (Mizutani, 2011). The regulatory framework was designed to assure the sustainable growth of the aviation industry and prevent excessive competition among Japanese airlines. Regulatory management continued for 15 years (until the mid 1980s) and contributed to increasing the number of international air passengers by 4.6 times and domestic passengers by 2.8 times (Inoue, p. 15, 2008). JAL and JAS were finally merged to compete against ANA in domestic market (Arai, 2004, Mizutani, 2011).

Revenue pooling has been essential to the continuous growth of the Japanese air transport system. This is a system of managing one unit's losses at the cost of another's profitability. For example, new airport construction was promoted through re-investments using the airport charge and fuel tax revenues of other airports paid by the airlines (Fig. 1.2). Airlines have maintained unprofitable airways using the revenues from profitable ones, with the losses of one airline compensating for the profits of another. Thus, Japan's air transport system has been developed and maintained through a business model in which profits are internally circulated throughout the system to generate growth. The function of the revenue pooling is similar to that of the Airport and Airway Trust Fund in the US where revenues from airport users are transferred for to the account for establishing the next development plan (Ohta, 1999). This business model functioned as long as the national economy developed consistently under the protective industrial growth strategy.

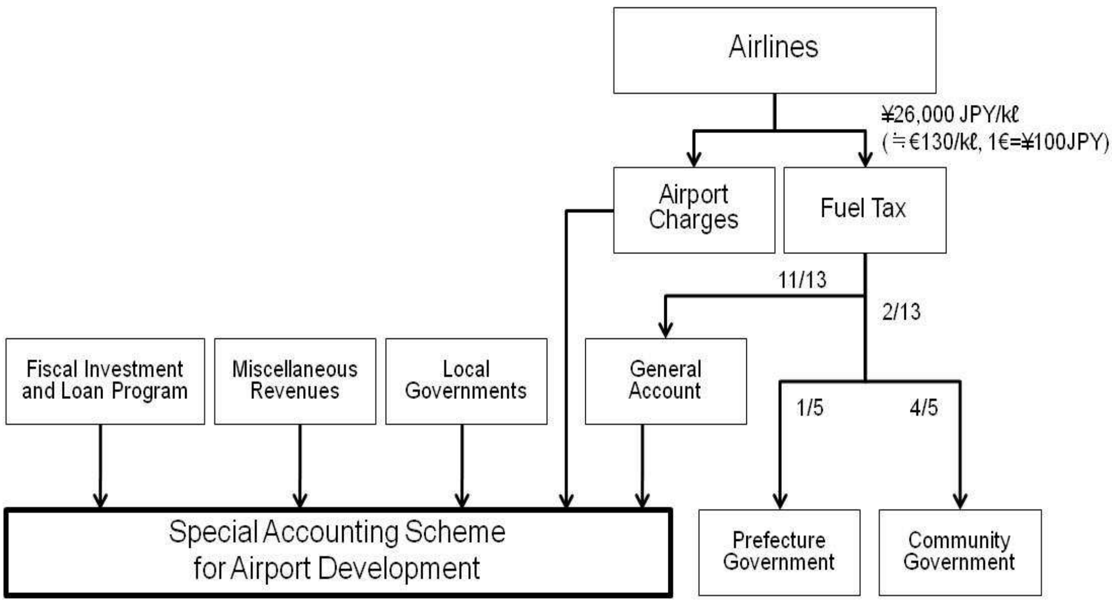


Fig. 1.2 Structure of Airport Development Finance in Japan

In the mid to late 1980s, however, air deregulation was introduced, and the Japanese economy began to decline, factors that gradually degraded the functionality of the business model based on the revenue pooling system. Air deregulation had started in the United States in the 1960s, and the Carter administration set off a chain of events that would gradually transform air transport from a closed and highly protected industry into a truly competitive business (Doganis, pp. 42-45, 2010, Graham, 2006, pp.76-93). The pressure for deregulation of international air transport services between the US and other countries became stronger in the 1980s, and has spread across the world (Ehmer, 2001, Endo, 2007).

Japanese air deregulation started in 1986. Thereafter, the government incrementally abolished regulations governing airways, airfares, and new airline entries until 2000. The policy of air deregulation obviously contributed to the growth of the air transport market in Japan. As indicated in Fig. 1.1, air traffic demand almost doubled during the decade after air deregulation began in 1986. On the other hand, the air deregulation forced Japanese airlines to cope with fierce market competition and thus they had to be sensitive to economic efficiency in order to manage profitability. They gradually started to exploit the freedom to retreat from unprofitable airways, especially from the regional airways, which lacked sufficient air traffic demand. The regional air transport network was no longer self-sustaining after the air deregulation (Matsumoto, 2007, Hashimoto and Yai, 2011). In other words, how to cope with the unsustainability has become the most important challenge for regional air transportation system today.

1.1.2.Global countermeasures and its problematic consequences

The common countermeasures for managing unsustainable regional air transport systems are mainly through subsidies, from either central or local governments. Since regional air transport greatly affects the development of regional economies (Graham, 2003), it is usually afforded special treatment. Governments subsidize aircraft purchases, reduce airport charges, compensate airlines for losses, and even guarantee flight load factors. In addition, governments encourage local residents to fly by offering them subsidized discounted tickets.

For example in the United States, Essential Air Service (EAS) provides a minimum level of air transport service for residents in geographically isolated areas. It guarantees all U.S. citizens rapid transport to all U.S. cities using nearby regional airports (Grubesic and Matisiw, 2011). In Europe, Public Service Obligation (PSO) provides financial support for commercially unfeasible regional flights. In Japan, air transport to remote islands is supported most strongly by the national subsidy program implemented under the Remote Island Encouragement Law (Hashimoto and Yai, Chapter 8, 2011. Matsumoto, 2007), in his study of regional air transport to remote islands in Nagasaki, points to the importance of government subsidies and airport construction. In short, most countries attempt to sustain unprofitable regional air transport systems through public debt.

However, I think that sustaining a regional air transport system through public debt is problematic especially in Japan for two reasons. The first reason is Japan’s shrinking population. Contrary to the global situation, Japan’s population has been decreasing after reaching its maximum of 127,787,000 in 2004 (Fig. 1.3). It is expected to continuously decrease for the next few decades, bringing a corresponding reduction in the working population (from 15 to 64 years old) and tax revenues (National Institute of Population and Social Security Research, 2012). Subsidies require cash investments from governments, but the source of that cash is under threat. The drastic increase of senior population (Fig. 1.4) makes the situation further worse. The decreasing working population must bear the cost of sustaining the aging society in Japan. Regional air transport system cannot be sustained solely on public finance and thus we need to have new measures to manage it.

The second reason is government debt. Fig. 1.5 represents the government debt to GDP ratio for the seven most developed countries from 1995 to 2010 (Ministry of Finance, 2010). Japan's ratio was under 100% in 1995 but dramatically increased, reaching almost 200% in 2010, the worst debt to GDP ratio among the seven. It implies that the Japanese government is not likely to be able to afford the subsidies required to sustain an unprofitable regional air transport system. The revenue decrease and debt increase make it clear that we should redesign Japan's regional air transport into a more self-sustaining system (Okamura and Minato, 2012).

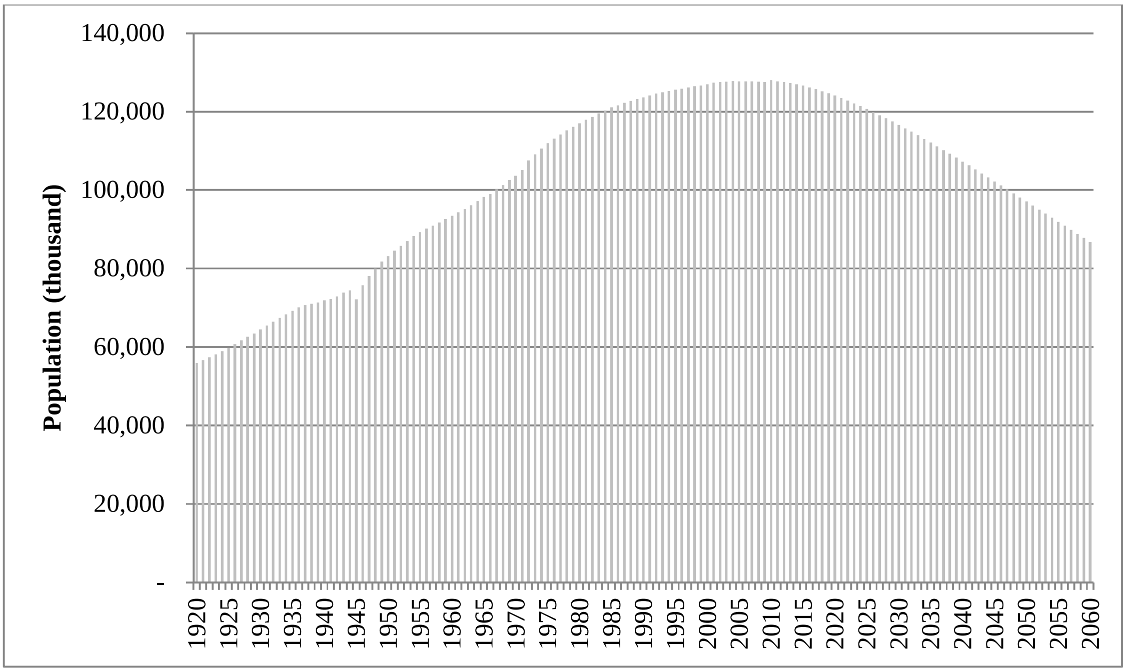


Fig. 1.3 Population of Japan (1920–2060)

Source: National Institute of Population and Social Security Research (2012)

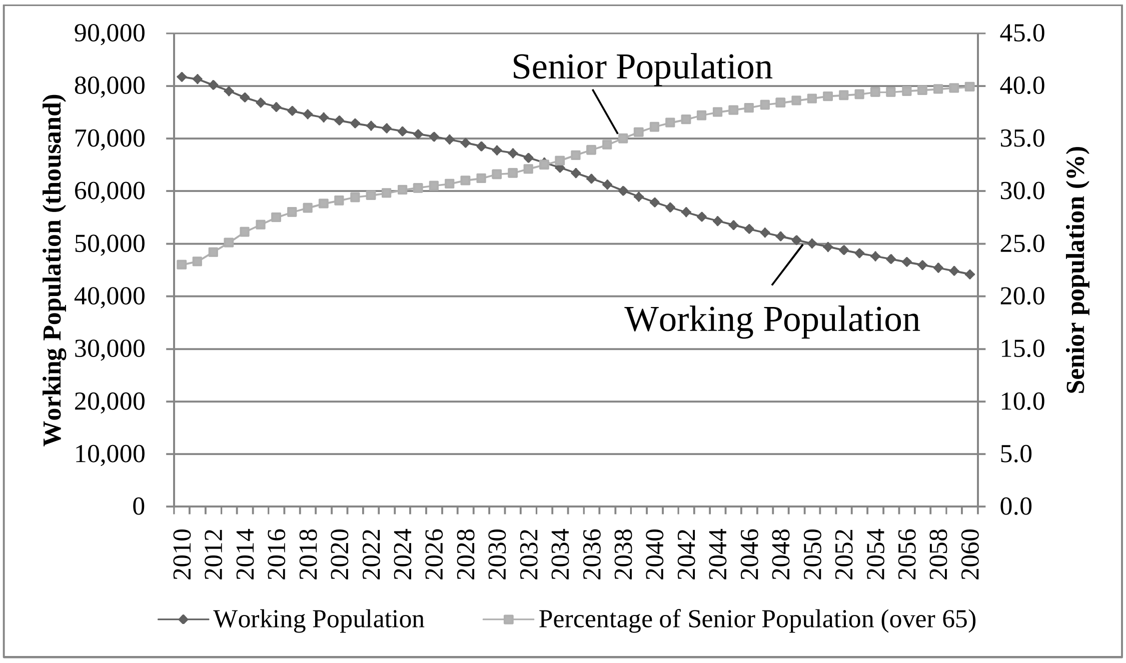


Fig. 1.4 Working Population and Senior Population (2010–2060)

Source: National Institute of Population and Social Security Research (2012)

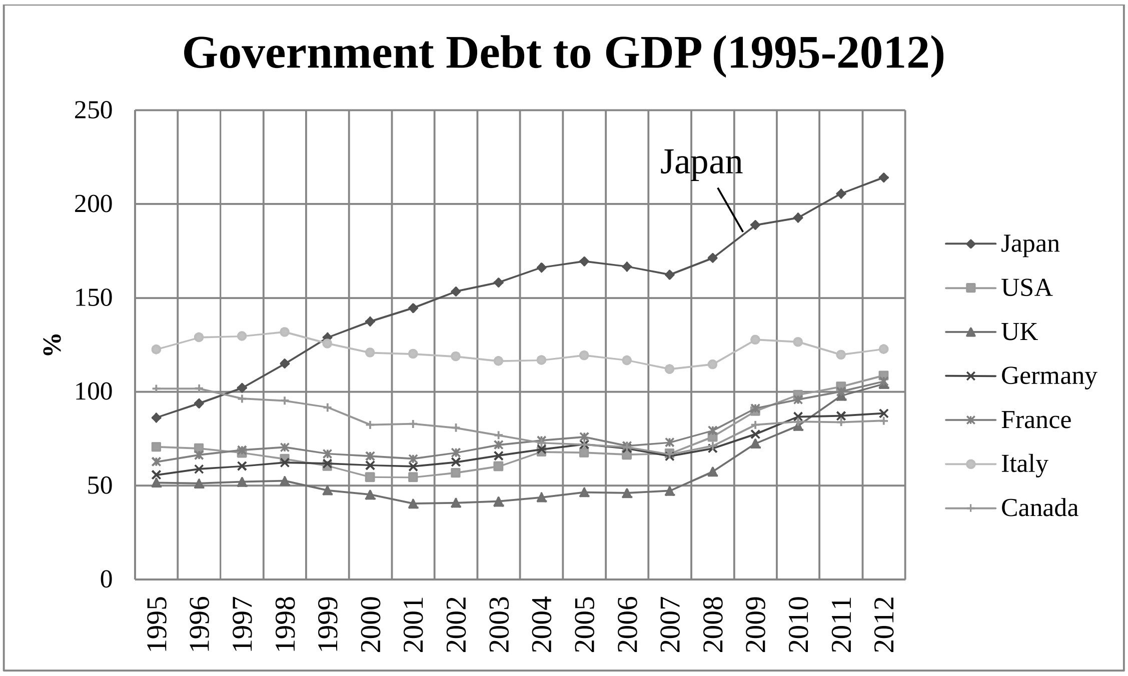


Fig. 1.5 Government Debt to GDP Ratio (1995–2012)

Source: Ministry of Finance (2012), originally OECD "Economic Outlook 91"

Furthermore, it has also been common practice for central and local governments to finance their airport developments through a combination of public debt supported by tax revenues and user fees but the demands resulting from the growth in the aviation sector have stretched government resources to the limit (Hooper, 2002). Considering the depopulation and the aging society mentioned above, this is really the case with Japan in the near future and therefore, it is necessary to transform unsustainable regional air transport system to be a more self-sustained system.

1.2. Research Motives

The unsustainability of Japan’s regional air transport system have been issues for me for many years, motivating me to study aerospace management in Europe for my master’s degree and work at Avion de Transport Regional (ATR) in Toulouse, France, in order to better understand management of regional air transport system.

Fig. 1.6 ATR-42 and ATR-72

Source: ATR Website, http://www.atraircraft.com/mediagallery/pictures.html

One of the world leaders in aircraft manufacturing, ATR produces two types of regional turboprop aircraft with 50 to 70 seats, the ATR-42 and ATR-72 (see Fig. 1.6). I was in charge of their Asian strategic regional air transport analysis. I believed that introducing an economically efficient aircraft would greatly contribute to solving the problems of the unprofitability and inefficiency of the regional air transport system. This was partly true, especially as fuel efficiency has become a key success factor for airlines that have coped with the drastic oil price increases since 2007. Yai and Hashimoto (2011) insist that inefficient fleet utilization is also an essential cause of the unprofitability of Japanese regional air transport. For example, Boeing 747s has been used for domestic flights in Japan until recently, preventing Japanese airlines from strategically introducing smaller aircraft to develop regional airways. They also argue that introducing appropriate sized regional jets would produce innovation in Japan's regional air transport market (Yai and Hashimoto, p. 3, 2011). I believed that the aircraft was the key issue.

However, through my work at ATR, I concluded that the aircraft was only part of the value chain of a regional air transport service and that the issue was much more complex. Regional air transportation is a multi-stakeholder system in which airlines, airports, aircraft, governments, communities, and other players mutually interact to bring passengers from an origin to a destination. It means that concentration on a part of a system does not always lead to entire performance improvement. For example, increase of frequency in air transport service consumes slot capacity at airport and might require additional capacity increase (Fig. 1.7). When air traffic increases at airport, it might require more drivers, vehicles and fuels of ground transportation to carry the passengers to their final destinations (Fig. 1.7). A systematic analysis is inevitable for an understanding of the interactions of the multiple stakeholders who embody the system's complex behaviour: 'It is important that a proactive and robust policy is developed that balances the various interest of the stakeholders' (Humphreys and Francis, 2002b).

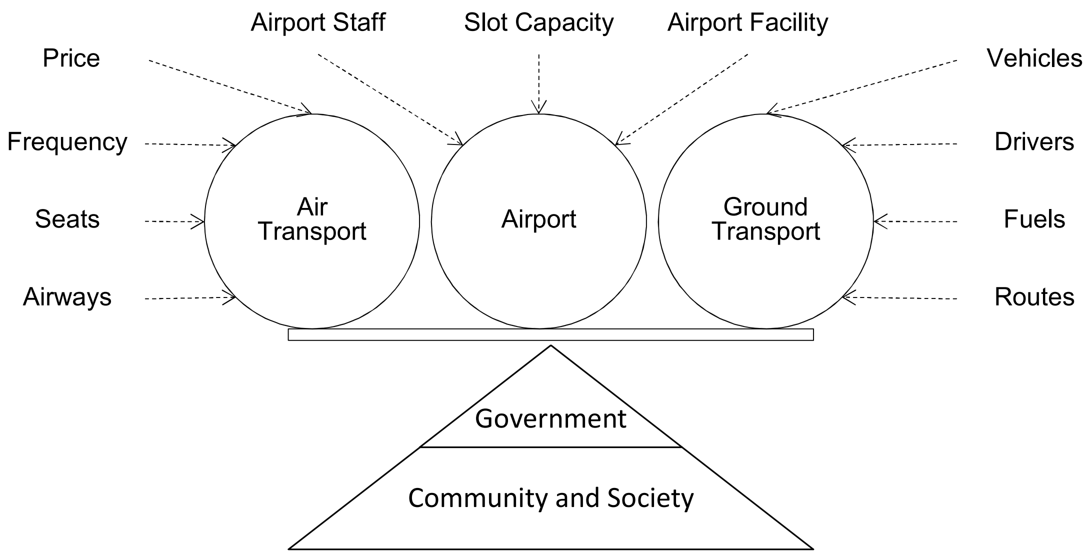


Fig. 1.7 Air transportation service system view

With the motives of understanding and analysing the complexity of regional air transport system, I started to study systems management theory and systems engineering. I introduced Systems of Systems (SoS) concept in this study, which is defined as "system elements are themselves systems; typically these entail large-scale inter-disciplinary problems involving multiple, heterogeneous, distributed systems" (INCOSE SE Handbook, p11, 2010). The interoperating collections of components of systems usually produce results unachievable by the individual systems alone (INCOSE SE Handbook, p11, 2010).

Therefore, I strongly came to conclusion that systems evaluation was inevitable for solving the issues. Furthermore, since regional air transport is operated by commercial entity, sustainability as a business system is essentially important for continuous provision of air transport services to communities. But we do not have a methodology for evaluating sustainability of business systems. I think that the lack of methodology has made the situation unimproved and further worse today.

1.3. Research Purpose and Target

1.3.1. Research purpose

The purpose of my doctoral thesis is thus to propose an integrated methodology to evaluate sustainability of business systems and to apply it for transforming unsustainable regional air transportation to be a more self-sustained system.

1.3.2. Application Target

I decided to deal mainly with Japanese regional air transport system. I think that Japanese regional air transportation is the most difficult to be commercially managed for two reasons. The first reason is insufficient public supports from government. As I explained above, there are national level subsidy programs for unprofitable regional air transport both in the U.S. (Essential Air Transport Service) and in Europe (Public Service Obligation). But such national level subsidy is provided only with remote island flights in Japan. It implies that regional airways connecting airports on mainland Japan is not supported by the subsidy program no matter how unsustainable they are. Secondly, there are severe competitions between air transportation and high-speed trains, Shinkansen (Minato, 2007). Furthermore, highway transport networks are well established in Japan and thus the competition is also against highway bus (Minato, 2007). In short, regional air transport in Japan is not fully supported by the government while it needs to commercially compete with other ground transport measures. Therefore, if I could find solutions for Japanese regional air transport system which I think is under the most sever conditions, I believe the methodology can be applied to overseas countries as well. Although I discuss several cases and literature involving overseas countries, I mainly focus on domestic regional passenger flights in Japan for this reason. International and air cargo flights are excluded from the research scope.

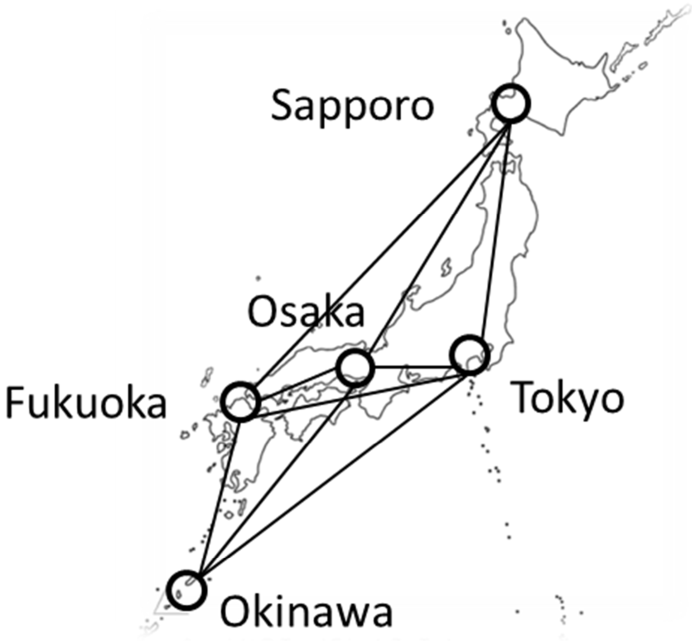


Fig. 1.8 Mainline flights in Japan

Source: Air transport statistics, MLIT (2012)

The ‘regional air transport’ concept is defined many ways in many countries. I use the definition of ‘local flight’ followed by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of the Government of Japan (GOJ). According to the MILT definition, all domestic flights in Japan are divided into two categories: 1) mainline flights and 2) local flights. Mainline flights are the air transport services connecting either two major Japanese cities, such as Tokyo (Haneda and Narita), Osaka (Itami and Kansai), Fukuoka, Sapporo, and Okinawa (Naha) (see Fig. 1.13). Local flights are all other flights. This research analyses the local flights suffering chronic unprofitability. Profitable local flights are excluded from the research scope, even when categorized as ‘local’ according to the MLIT definition.

1.4. Research Problems

I have discussed the unsustainability issues with a variety of Japan's air transport regulators, industry, research institutes, and community in Japan. They have provided with me interview opportunities and valuable data for quantitative analysis as well as thoughtful insights on the air transport system issue. Resultantly, the following two arguments have been identified as critical challenges for the business practitioners today.

1.4.1. How to sustain a flight to Tokyo

The first argument flows from the socio-geographical issues. Tokyo is Japan's largest economic and political city and is located at its centre. It generates 33.2% of Japan's gross commercial sales, and 48.7% of Japan's private companies capitalized at over 1 billion JPY are located there (Tokyo Metropolitan Government, 2006). Thus, the economic concentration on Tokyo is a critical issue for Japanese society and its aviation industry. In fact, approximately two-thirds of all Japanese domestic air passengers travel to Tokyo (Ministry of Land, Infrastructure, Transport and Tourism, 2005). Despite the concentrated air traffic demands on Tokyo, Tokyo International Airport (Haneda) is virtually the only landing site in the area. Narita International Airport is in the prefecture next to Tokyo, but it is 'famous for its high unit access cost from each city centre' (Yoshida and Fujimoto, 2004). Due to the insufficient landing capacity at Haneda airport, local Japanese cities have been suffering from a lack of direct flight access to Tokyo even though their lives and economies are greatly dependent on the activities there (Takebayashi, 2011, 2012). The problem is worsened by the special regulation at Haneda Airport forbidding any small aircraft with fewer than 60 seats from landing in order to cope with its high air traffic demand (Aviation Statistics 2009). Local Japanese cities thus miss an opportunity to increase their air traffic demand by operating direct flights to Tokyo, keeping both regional airlines and airports unprofitable.

Appropriate aircraft size has been discussed for solving the issue. Yai and Saito

(2002) discuss improving unprofitable regional airways by introducing small aircraft. In fact, the Japanese government is planning to expand the capacity of Haneda airport by constructing a new runway, which ‘will allow the airport capacity to increase significantly, from the current 285,000* to 407,000 per year, in order to enlarge its domestic aviation network’ (Ministry of Land, Infrastructure, Transport and Tourism, 2010). They have concluded that passenger convenience would be further improved through the combined utilization of large and small aircraft at Haneda airport, assuming the construction of a runway devoted to small aircraft.

Japanese government expanded the landing slot capacity at Haneda Airport by 2010. However, the government also intended to strengthen international competitiveness of Haneda Airport and thus 90,000 out of 110,000 increased slot capacities were allocated to international flights rather than domestic local flights (MLIT, 2010). As I discussed, air transport management is a system issue, thus allocating slot capacity to small aircraft results in aggravation of airport efficiency. Downsizing of an aircraft can technically solve the connection flight issue but brings about strategic collisions with Japanese government internationalization policy on aviation. It implies the necessity for systematic solutions considering all air transport stakeholders’ interest other than the size of aircraft.

1.4.2.How to manage demand thinness and fluctuation

The second argument relates to the nature of regional air transport. Air traffic demands are generally thin due to the remoteness of the locations involved, where the economy is relatively weak. In addition, demand fluctuation is high due to seasonality. Fig. 1.9 shows a comparison between the monthly air passengers of local and mainline airlines from 2008 to 2010 (Air Transport Statistics, MLIT, 2010). It clearly illustrates that local flights experience much more demand fluctuation than mainline flights. The standard deviation of the mainline is only 289 while that of the local reaches as high as 506 during the peak period.

In addition, Fig. 1.10 shows a comparison between the monthly load factors of local and mainline airlines from 2008 to 2010 (Air Transport Statistics, MLIT, 2010). It illustrates that local flights had a much lower load factor than mainline flights throughout almost the entire period, suggesting that local flights have a much thinner air traffic demand. In order to cope with this thinner and more widely fluctuating air traffic demand, regional airlines and airports simply rely on governments. In other words, public assistance is required to sustain a regional air transport system in the market. But as I discussed above, Japanese government is unlikely to be able to afford the subsidies required to sustain all the unprofitable regional airways.

Other than providing subsidies, another major approach to the demand thinness is the introduction of Low Cost Carriers (LCCs) (Hanaoka and Saraswati, 2011). Traditionally, regional airports have been feeder points in network carriers' hub-and-spoke systems or destinations for seasonal charter traffic (Lei and Papatheodorou, 2010). The introduction of LCCs enabled regional airports to work in a way different from that of traditional airlines by drawing passengers from a wider catchment area (Barrett, 2000). Thus, some regional airports have eagerly introduced LCCs, and some have succeeded in attracting younger, more price-sensitive travellers (O'Connell and Williams, 2005, Castillo-Manzano, 2010). However, not all regional airports are located near metro regions, and thus not all can become secondary airports, a factor key to the success of LCCs (Zhang et al., 2008). This approach is not likely to be an effective solution especially for regional airways with thin air traffic demands.

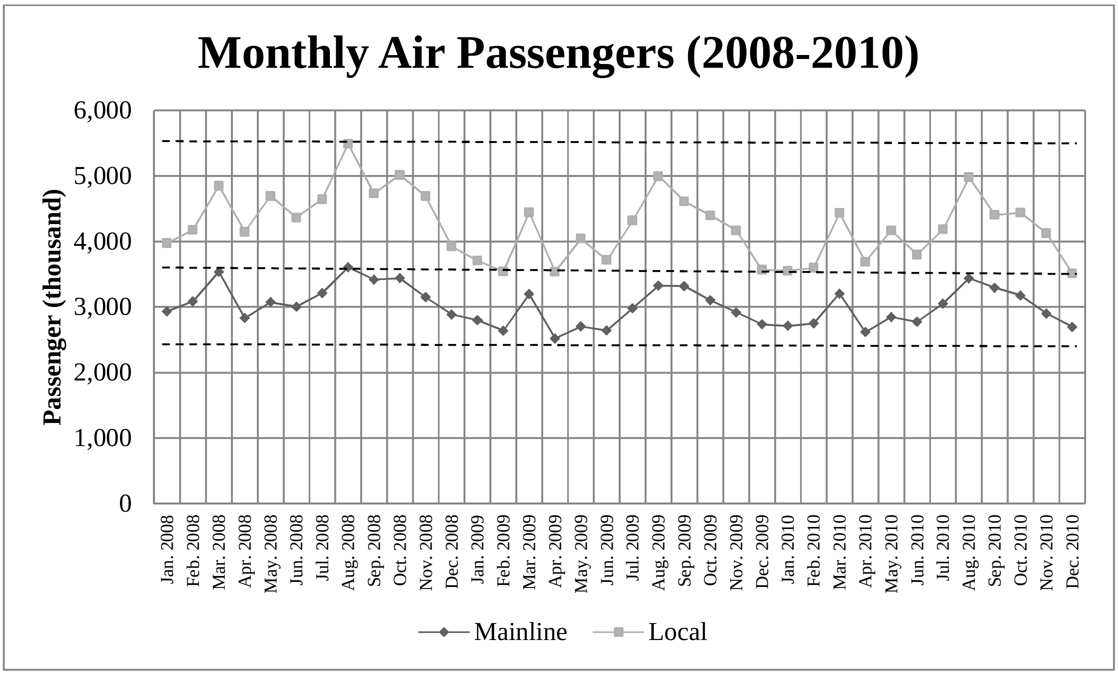


Fig. 1.9 Monthly air passengers in Japan (MLIT, 2008–2010)

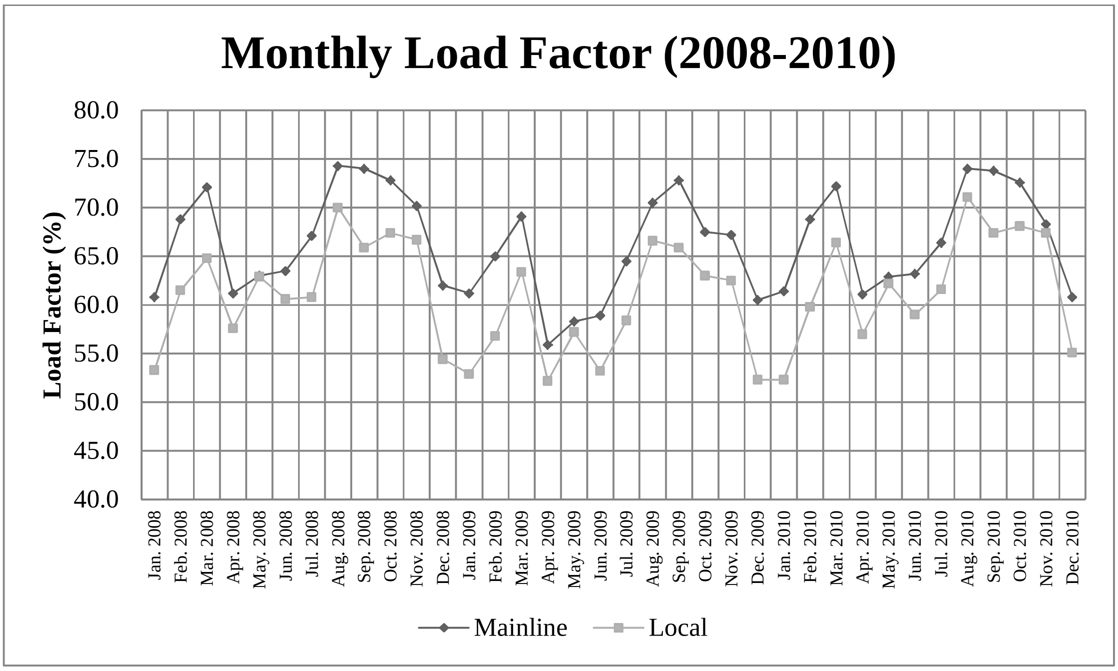


Fig. 1.10 Monthly load factor in Japan (MLIT, 2008–2010)

1.5. Research Strategy

Before air deregulation, the Japanese regional air transport system was maintained through a pyramid structure. On the top was the Ministry of Transport (MOT), which regulated the aviation industry. At the bottom were small regional airlines, most established with the financial aid of local governments. In the middle, the three major Japanese airlines—Japan Airlines (JAL), All Nippon Airways (ANA) and Japan Air System (JAS)—operated both domestically and internationally. The strong hierarchy of its air transport system mirrored Japan's centralised governance structure (Feldhoff, 2002, 2003). Because the hierarchy had order and control, its business relationships were rather characterized as protection.

However, air deregulation broke this equilibrium, and airlines and airports began to compete with each other (Barrett, 2000). Under free competition, the strong remained while the weak were eliminated from the market. Therefore, some regional airlines and airports relied on government subsidies to remain in the market. Two evolutionary trends emerged in Japan's regional air transport system—a transformation from a protective system into a competitive one (see Fig. 11.2, bottom left) and then a transformation from a competitive system into a parasitic one (see Fig. 11.2, top right). Some player can compete in the market but those who are unable to compete do nothing but either retreat from the market or depend on public subsidy to stay in the market.

However, the anticipated social changes will not allow us to maintain the regional air transport system using such conventional approaches. Therefore, this research attempts to transform regional air transportation from a competitive system (see Fig. 11.2, bottom left) or parasitic system (see Fig. 11.2, top right) into a symbiotic system (see Fig. 11.2, bottom right). It implies that each regional air transport stakeholder bilaterally relies on the others while coexisting in a market rather than competing with the others or being parasitic on external resources such as public financing. The methodology in this research can integrally guide the transformation of the public-dependent air transportation to be more market-oriented, self-sustainable business systems (Fig. 1.11).

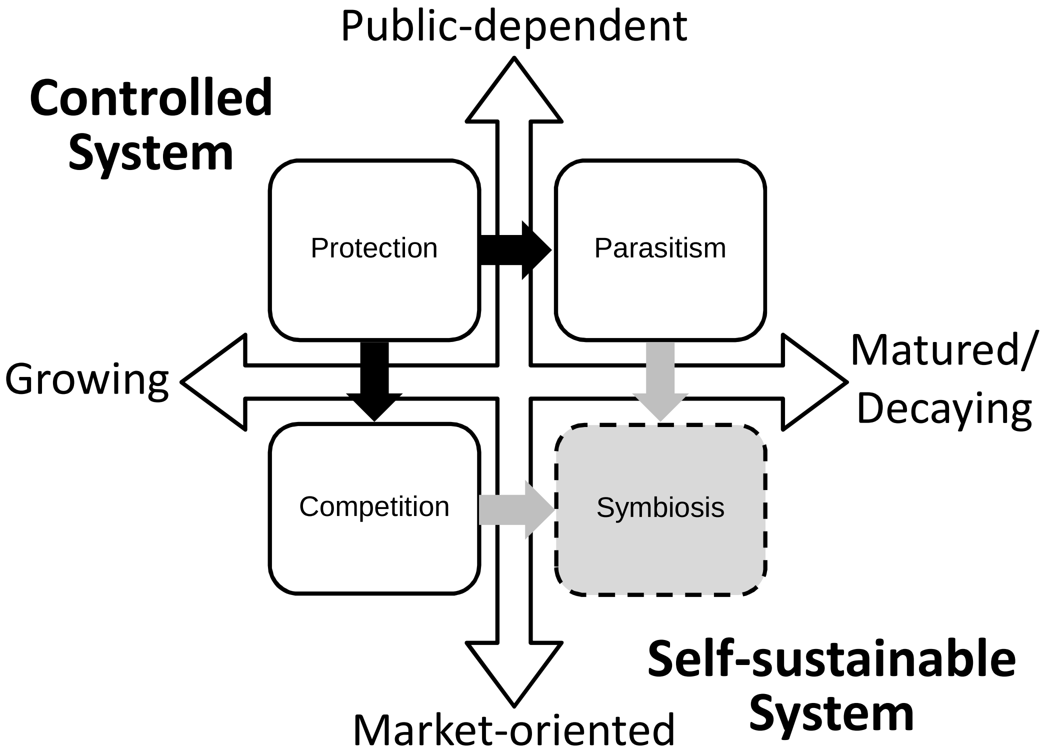


Fig. 1.11 Strategic direction of the research

However, evaluating sustainability of business systems is very difficult. It is mainly because of the interactions of multiple business stakeholders which bring about non-linear, complex system behaviours overtime. The non-linearity prevents conventional approaches such as statistics and multivariate analysis from clearly understanding long-term sustainability of business systems. I introduce systems evaluation approach in this research. Systems approach is generally defined as “a holistic multidisciplinary methodology for analysing, evaluating and optimizing a complex system understanding how elements are interacting with each other within a whole system” (Nakano and Minato, 2012).

One of the effective analytical measures in systems approach is System Dynamics (SD). It was developed by Jay Forrester of MIT in the 1950s so as to model the nonlinear dynamics of complex systems (Sterman, 2000, Nakano and Minato, pp. 79-88, 2012). The application of SD theory to business systems evaluation was comprehensively studied by John Sterman (2000). He argues that business systems have a typical behaviour overtime caused by its system structure (Sterman, 2000). What we can obverse in reality is results of business systems. The results are caused by the behaviour of business systems. The behaviour of business systems is caused by the structure of business systems. Therefore, in order to change the results effectively, we must first analyse and change the structure of business systems.

There are six typical behaviours according to Sterman: 1) Exponential Growth, 2) Goal Seeking, 3) S-shaped Growth, 4) Oscillation, 5) Growth with Overshoot and 6) Overshoot and Collapse (Fig. 1.12). Whenever a particular pattern of behaviour is observed, it is possible to estimate what types of feedback structures must have been dominant during the period covered by the data (Sterman, 2000).

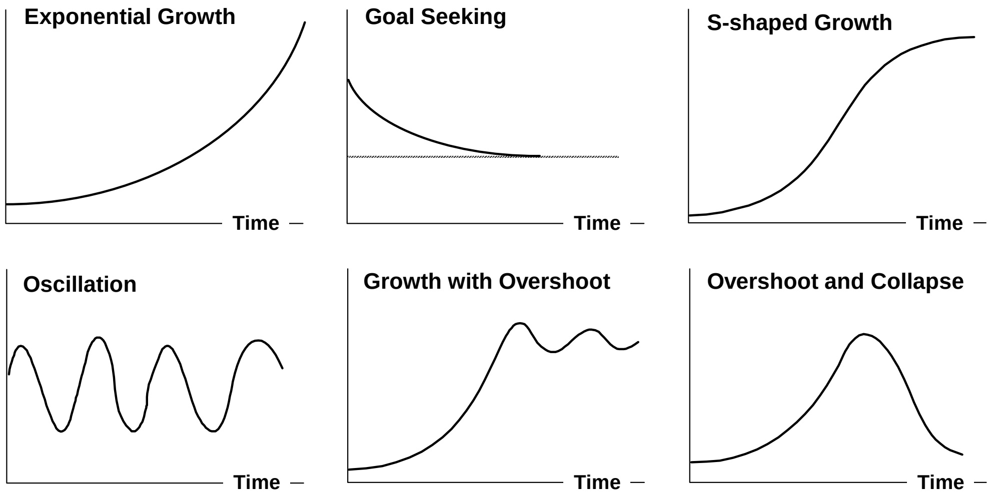


Fig. 1.12 Fundamental Modes of System Behaviour
(Adopted from Sterman, p.108, 2000)

On the basis of the Sterman's works, I articulated three problematic behaviours in business systems that particularly hinder sustainability: 1) oscillation, 2) decay and 3) undergrowth.

Oscillation means instability of business systems and occurs anytime during business lifecycle. In most businesses, demand fluctuation can be a major source of oscillation. We must bear such demand risk as long as we operate business in a free market economy. Thus, stability of business systems is a fundamental factor to be evaluated for business sustainability.

Decay occurs especially in the last stage of business lifecycle. It is partly because of erosion of the market capacity enough to sustain the business profitability and partly because of socio-economic factors such as depopulation and aging society. Furthermore, there is a disruption of demand and supply with a certain probability during the long course of business operation. Durability of business systems is also a fundamental factor to be evaluated for business sustainability.

Undergrowth means that business systems are not able to grow up to the maximum of its potential. It is partly because of losing competitiveness in the course of market competition or partly because of uncertain events such as new players' market entry or a new regulation introduction from governments. In addition, business systems are generally composed of multiple stakeholders and organizations. In order for business systems to continuously grow, every business element must be properly integrated for efficient operation. Competitiveness, uncertainty and business integration must be systematically evaluated for sustainable growth of business, which I define as scalability of business systems in this research.

In summary, Fig. 1.13 describes the three fundamental questions to be addressed for evaluating sustainability of business systems: 1) how to stabilize, 2) how to endure and 3) how to grow. Each question is thoroughly discussed with concrete business examples from Chapter 4 through Chapter 10.

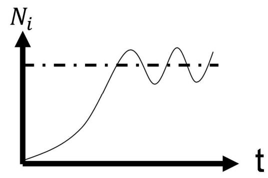
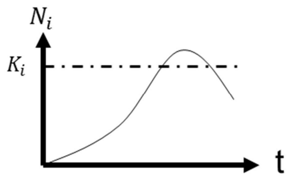
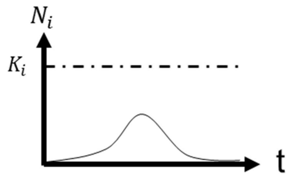
	Oscillation	Decay	Undergrowth
Problematic Behavior			
Question	**How to stabilize?**	**How to endure?**	**How to grow?**

Fig. 1.13 Fundamental questions for business sustainability

1.6. Thesis Structure

This thesis comprises 5 parts that are divided further into 11 chapters, as shown in Table. 1.1.

Part 1 is consisted of Chapter 1 through Chapter 3. Chapter 1, the introduction, presents an overview of my doctoral research; the research background, motives, purpose, problems, thesis structures are explained. Chapter 2 is the literature review. It summarises the extant research on regional air transportation and sustainability evaluation and discusses management practices on regional air transportation worldwide, allowing me to highlight the originality of my research. Chapter 3 explains systems evaluation framework for business sustainability.

Part 2 is consisted of Chapter 4 and Chapter 5 and deals with stability of business systems. Chapter 4 discusses the challenge of airline and airport relation when there are multiple airways. Portfolio theory drawn from financial analysis is used to look at ways of reducing the business risks of a regional air transport through the diversification of destinations. I examine remote island flights in Japan as they are the most difficult to commercially manage. Chapter 5 discusses airline and airport relation again where there is only a single airway. Both parties are critical for providing an air transportation service to regional community; therefore, their mutual relationship must be healthily maintained. I examine management of air transportation to a peninsula as it is far away from the mainland, air transport, rather than ground transport, generally plays an essential role.

Part 3 is consisted of Chapter 6 and Chapter 7 and deals with durability of business systems. Chapter 6 discusses air transportation ecosystem. On the basis of the same example of air transportation to a peninsula, I examine the broader scope of regional air transportation stakeholders' interactions, such as local governments and communities. Chapter 7 discusses air transportation and disaster. The abovementioned approaches are used mainly to manage the weaknesses of regional air transport, while the chapter aims to transform the weaknesses into strengths by finding a new social *raison d'etre* for regional air transportation. I highlight the role of regional air transport in managing catastrophic natural disasters by examining the 2011 East Japan great earthquake and tsunami.

Part 4 is consisted of Chapter 8 through Chapter 10 and deals with scalability of business systems. Chapter 8 discusses competitiveness of business systems. A matrix operation model is proposed to systematically evaluate business competitiveness among multiple players from multiple perspectives. Chapter 9 deals with uncertainty in business system. Monte Carlo simulation model is proposed for evaluating financial risks associated with business systems. Chapter 10 comprises integration of several business elements into business system. System Dynamics is integrally used for evaluating feasibility, profitability and scalability of business system.

Finally in Part 5, Chapter 11 concludes my doctoral research; its limitations and possibilities for future research are outlined.

Table 1.1 Thesis Structure

		Chapter#	**Chapter Title**
Part 1	Issue, Literature and Theory	Chapter 1	Introduction
		Chapter 2	Sustainability and Air Transportation
		Chapter 3	Systems Evaluation Framework and Applied Technologies
Part 2	Stability of Business Systems	Chapter 4	Airline-Airport Symbiosis (Multiple-Airways)
		Chapter 5	Airline-Airport Symbiosis (Single-Airway)
Part 3	Durability of Business Systems	Chapter 6	Air Transportation Ecosystem
		Chapter 7	Air Transportation and Disaster
Part 4	Scalability of Business Systems	Chapter 8	Systems Evaluation on Competitiveness
		Chapter 9	Systems Evaluation on Uncertainty
		Chapter 10	Systems Evaluation on Business Integration
Part 5	Summary	Chapter 11	Conclusions

(Intentionally Blank)

Chapter 2. Sustainability and Air Transportation

This chapter discusses the concept of sustainability, its original meaning and limitation for applying to business systems evaluation. Then I review major literature on system evaluation methods and regional air transportation researches from sustainability perspective. Although the focus is on domestic, scheduled passenger flights in Japan, I discuss several overseas cases in the U.S. and Europe to compare their management practices regarding regional air transportation. The originality of my doctoral research is also highlighted in this chapter.

2.1. Reconfiguration of Sustainability Concept

2.1.1. Conventional definition and its limitation

The concept of sustainability was originally introduced for conserving natural resources in fishery industry under the resource constraint (Utne, 2007) and the idea was further expanded to discuss other industrial sectors as well (Lien et al., 2007, Fenley et al., 2007, Gunasekarean and Spalanzani, 2012). In 1987, Brundtland report clearly defined the sustainable development concept as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland Group, Chapter 2, 1987). The definition has widely been accepted among researchers and practitioners and popularly utilized today (Morimoto, 2010). In addition, three common pillars of interests are often discussed in terms of sustainable development: Environment, Economy and Society (Fig. 2.1). They are called “triple bottom-line” (Savitz and Weber, 2006). The overlapped intersection is called as “sustainability sweet spot” (Sharma et al., 2010).

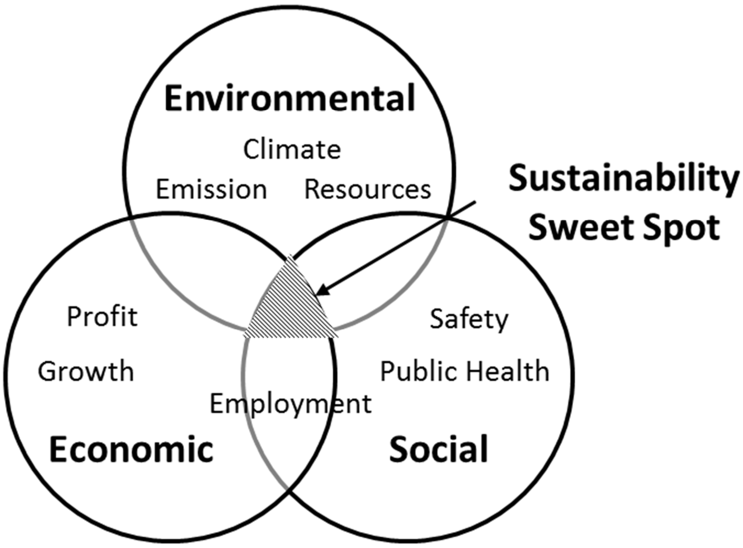


Fig. 2.1 Three Pillars of Sustainability (Triple Bottom-line)

Environmental pillar includes discussions such as climate change, emission and scarcity of natural resources. Economic pillar includes discussions such as profitability of business and growth of market. Social pillar includes discussions such as safety of life and public health. Employment can be an issue of both economic and social (Utne, 2007). Economic interests and the interests of environment and society intersect in every firm's operations and therefore we have to manage the overlap between corporate goals of increasing market share and profits and the environmental goals of addressing climate change and public health.

Thus, one of the difficulties for evaluating sustainability lies in integration of these multiple dimensions. As Utne (2007) indicated, it cannot be investigated within the limits of a single scientific discipline, because it involves several disciplines, such as ecology, economy, engineering, law, physics, politics, and sociology. He also pointed out the difficulty that the multi-disciplinarily introduces cross-disciplinary communication problems that causes conceptual difficulties and unclear measures of sustainability (Utne, 2007). Hence, I identify that integration of different dimensions is the first challenge for evaluating of business sustainability.

Furthermore, most researchers' efforts are concentrated on considering the sustainability sweet spot (Fig. 2.1). Specifically speaking, they tend to discuss it merely from environmental aspects such as CO2 emissions, NOx emissions and noise issue from aviation industry (Graham and Guyer, 1999, Gudmundsson and Anger, 2012). Despite the criticality of sustainability issue, business-oriented sustainability is not fully examined in air transportation. I think it is mainly due to the ossification of sustainability concept such as triple bottom line and sustainability sweet spot (Fig. 2.1), which are commonly accepted worldwide. Ironically speaking, the trends of sustainability analysis have long been ossified among researchers and practitioners. Thus, the challenge is reconfiguration of sustainability concept.

When it comes to the original meaning of sustainability, we can easily notice that the concept is not limited to environment, economic and social consideration. Rather, the Brundtland definition provides two essential implications on sustainability. For one thing, we must consider balances of benefits and risks associated with a target. For another thing, we must explore success in the long run. The triple bottom-line argument also suggests that we must evaluate multiple stakeholders' interest and a well-balanced consideration of each interest is important for sustainability. In short, balance, long-term perspective, multiple stakeholders are essential keywords for sustainability evaluation.

2.1.2. New Typology of Sustainability

There are several ways to accomplish sustainability of business systems. For example, regardless of time horizon, business can generally be sustained as long as government protect the entire business system. They can also be sustained by continuous supply of external resources. Thus I would like to propose the following new typology: 1) protective sustainability, 2) competitive sustainability, 3) parasitic sustainability and 4) symbiotic sustainability.

For better understanding of each concept from system perspective, I used the graphical notations (Fig. 1.14 to Fig. 1.18). In INCOSE definition, a system is “a combination of interacting elements organized to achieve one or more stated purposes” (INCOSE SE Handbook, ver.3.2, 2010). In a normal state, thus, a system can be simply visualized as in Fig. 1.14. System boundary is described in a rectangle. Dotted line of the rectangle means the boundary is flexible or uncertain. System elements are described in circles. Solid circle means the element is efficient and dotted circle means the element is inefficient. The interactions of elements are described in lines between the elements. A dotted connection line means the relation is flexible and solid connection line means the relations is fixed. The figure represents that multiple elements within a system interact with each other to perform defined objectives.

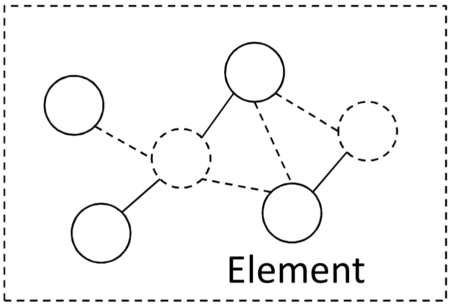


Fig. 2.2 Nominal State of System

The first type of sustainability is protective sustainability. It implies that a system is sustained by protection of the system’s owner or any external authority. For example, an emerging industry is usually protected by government for a time being for sustainable growth of the market preventing excessive competitions. In other words, governments define and control boundary, elements and relations within business systems for realizing its sustainability. System configuration is fixed as in Fig. 1.15. Solid line of the rectangle means the boundary is fixed by the protections. Protective sustainability is effective when business systems are in the early stage of its lifecycle. However, in the matured stage, the protection easily becomes the burden of those who are responsible for. Thus, the application is limited.

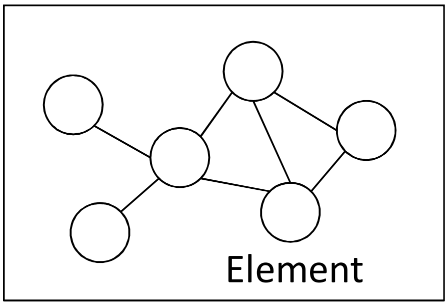


Fig. 2.3 Graphical Expression of Protective Sustainability

The second type is competitive sustainability (Fig. 1.16). When a part of a system is found as inefficient and influence its sustainability, we tend to improve it coping with the inefficient element. Generally, it eliminates inefficient elements from a system to improve system's total performance. Under this strategy, competitive evaluation is usually introduced among the elements and relatively inefficient elements are excluded. In other words, sustainability of business system is realized through competitions. Natural selection in a market competition is an example. The problem of competitive sustainability is that it easily ignores what is eliminated. For enhancing efficiency of entire system, a part of the system is scarified. It implies that competitive sustainability can be a solution for macroscopic business systems improvement but not for microscopic business system improvement. It can solve entire air transportation system but cannot solve individual regional airway. Thus, the application is limited.

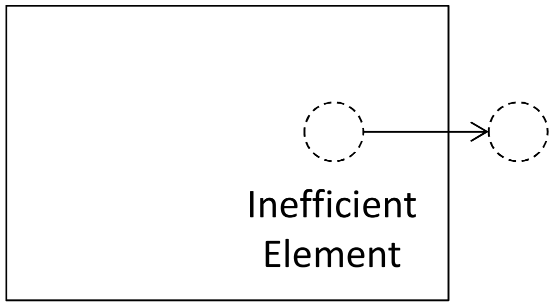


Fig. 2.4 Graphical Expression of Competitive Sustainability

The third type is parasitic sustainability (Fig. 1.16). It tries to manage inefficiency of a system depending on external resources. A system itself is not self-sustainable; therefore, sustainability of system is realized through parasite on something outside its boundary. For example, government usually provides subsidies for unprofitable public services operated by private entities especially when the services are inevitable for society. The problem of parasitic sustainability is that it temporarily solves the issue but not in the long run. Contradictory speaking, it is unsustainable sustainability. Thus, the application and effectiveness is limited.

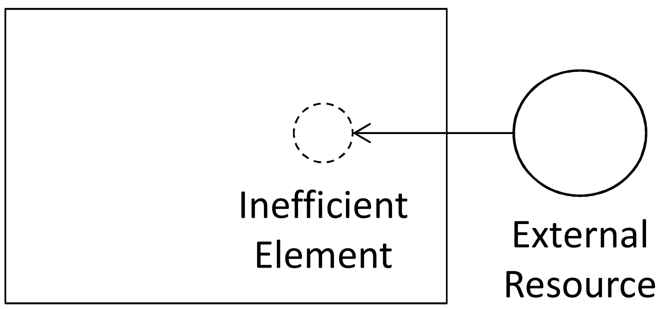


Fig. 2.5 Graphical Expression of Parasitic Sustainability

The last type is symbiotic sustainability (Fig. 1.17). It tries to sustain inefficient elements within a system by designing a co-existence. To put it more concrete, it regards two or more inefficient elements as a single entity which shares the same fate and explore mutually beneficial relationship. It implies that each stakeholder bilaterally relies on the others while coexisting in a market rather than competing with the others or being parasitic on external resources such as public financing. Considering the depopulation and the aging society discussed above, I think that symbiotic sustainability is more required in society than before.

Symbiosis is a term originally adopted from biology and ecology. It is defined as ‘biological, long-term, interactive relationship between two different species that live close together and depend on each other in particular ways’ (Oxford Dictionary). Thus in this research, I define symbiotic sustainability of business system as ‘commercial, long-term, operationally interactive relationship between two or more different players that run a business close together within a specific market’ (Yukalov et al., 2012). It implies that each regional air transport stakeholder bilaterally relies on the others while coexisting in a market rather than competing with the others or being parasitic on public financing. The ultimate objective is thus not to win a competition but to sustainably coexist in a market to meet the present and future needs of society.

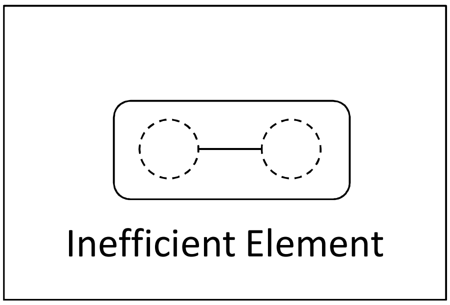


Fig. 2.6 Graphical Expression of Symbiotic Sustainability

Ecological metaphors such as symbiosis have been widely used in business ecosystem analyses (Moore, 1993; Iansiti and Levin, 2004). A business ecosystem is defined as a network of suppliers and customers around a core technology platform who depend on each other for their success and survival (Den Hartigh and Asseldonk, 2004, Den Hartigh et al., 2005), including not only the direct contributors to the production and delivery of products and services but also the indirect contributors, such as competitors and customers (Zhang and Lian, 2011). This broader scope of systems analysis is necessary to cope with society’s increasing complexity. However, previous researches are limited either to conceptual framework proposal or qualitative case studies.

2.2. Researches on Air Transportation

2.2.1. Protective Sustainability of air transportation

Many studies have attributed the unprofitability and inefficiency of Japanese regional air transport to the special accounting scheme used for airport development (Sasaki, 1986a, 1986b; Shomi, 1992, 1995, 1999a, 1999b, Kikuchi, 1999, Kamimura, 2002, Sato and Yamauchi, 2006, Kato and Sakakibara, 2006, Ishii, 2006, Akai et al., 2007, Kato et al., 2011). The argument is that the revenue pooling system (see Fig. 1.3) used among profitable and unprofitable airports has enabled and promoted the construction of unnecessary regional airports countrywide. New airport constructions were promoted through re-investments drawn from the airport charge and fuel tax revenues of the other airports originally paid by the airlines. This model functioned appropriately when the economy was growing, but inefficiencies began after the collapse of the Japanese economy in the 1990s. In other words, protective sustainability can be applicable in the early stage of business systems growth but not in the stages after the maturity. In this sense, it is not worth discussing as to Japanese regional air transportation.

2.2.2. Competitive sustainability of air transportation

Many researchers have also analysed the efficiency of Japanese airports based on statistical data analysis. Yoshida (2004) evaluates 30 Japanese airports using Total-Factor-Productivity (TFP) and finds that they show a strong increasing return to scale and require appropriate government intervention. Yoshida and Fujimoto (2004) evaluate 67 airports in Japan using Data Envelope Analysis (DEA) and find that airports on the Japanese islands are more efficient than those on the mainland. Yamaguchi (2007) analyses inter-regional air transport accessibility in 47 prefectures in Japan and finds that 'there have been significant productivity gains from improvement in air transport accessibility between 1995 to 2000 particularly in agglomerated areas such as the Tokyo metropolitan region'. Ozeki (2008) evaluates 53 airports in Japan using DEA and finds that airport productivity is positively correlated to the number of flights to Tokyo. Kato et al. (2011) analyse the financial records of 41 airports in Japan while considering depreciation costs and conclude that ‘airports managed by local governments were very difficult to sustain financially without subsidy’; 5.2 million passengers are required for profitability, but most regional airports have fewer than 2.5 million (Kato et al., 2011). Furuyama et al. (2010) evaluate 76 airports in Japan using DEA and propose the abolition of financial support for airlines because it promotes excessive competition among regional airports, invites new airlines through subsidies (e.g. through airport charge reductions), and worsens airports’ profitability. Barros et al (2010) evaluate 16 Japanese airports operating from 1987 to 2005 estimating Malmquist input-based index of total factor productivity to find that the airports on average became less efficient and experienced technological regress. Furthermore, Usami and Akai (2012) extend the scope of investigation to managerial performance of airport terminal buildings. They examined the financial performance of 58 airport terminal building companies in Japan using 7 years' panel data of 2003 to 2009. They found that airport terminal companies whose executive boards include larger fractions of retired government bureaucrats, and whose staffs include larger fractions of government workers on temporary assignment, have lower profit (Usami and Akai, 2012). Their argument implies that government intervention in the capitalization and governance of terminal building companies has fostered practices that impair their financial performance. Most researchers conclude that Japanese air transport system needs to increase their efficiency.

Enhancing efficiency of regional air transport system is a global issue. Papatheodorou and Lei (2006) analyse regional airports in UK using panel data and conclude that accessibility is crucial to improving revenue. Halpern (2010) surveys airport managers’ attitudes to marketing innovation in Europe’s peripheral areas and concludes that ‘innovation is significantly higher at airports that are administrated as an independent entity compared to airports that are administrated as part of a regional or national airport system’. His research suggests that their ownership form affects the commercial viability of regional airports. Marcucci and Gatta (2011) find that parking and connectivity were the most influential factors in Italian consumers’ choice of regional airports, suggesting that expanded parking may improve regional airports’ commercial sustainability when passenger traffic increases. In other words, commercial viability may be based not only on aeronautical revenues but also on commercial revenues from non-aeronautical activities: ‘A key development in the evolution of the airport industry has been the increase in the dependence on non-aeronautical or commercial revenues’ (Graham, 2003). Furthermore, airport activities contribute to local and national government revenues. Employees and consumers pay income and sales taxes. Private airports pay business taxes. Public airports pass a share of their earnings onto their government owners. In return, government owners have traditionally allocated considerable public sector funds to aid in airport development (Graham, 2003).

2.2.3. Parasitic sustainability of air transportation

The unprofitability and inefficiency of regional air transport is a global issue. National subsidies are a common countermeasure, especially when demand for air travel is slight at locations where air transport is important to the local economy. In the United States, Essential Air Services (EAS) provide ‘small communities throughout the United States and Alaska with a minimum level of air transport service, connecting them through carrier hubs to the national network’ (Grubesic and Matisiw, 2011). Fig. 2.5 shows an example of the EAS network in the U.S. (Matisziw et al. 2012). These small communities can use the subsidised money to attract new or additional air services (Santana, 2009).

In Europe, the Public Service Obligation (PSO) ensures ‘minimum’ levels of air service to remote areas by subsidizing non-commercial routes (Lian and Ronnevik, 2011). These programmes originated following deregulation and were developed to counteract its negative regional consequences (Lian and Ronnevik, 2011). Once awarded a PSO, airlines are granted a monopoly on the route for a period not exceeding three years (Williams and Pagliari, 2004). Ten countries applied to the PSO scheme in 2006: Finland, France, Germany, Greece, Ireland, Italy Portugal, Spain, Sweden, and the UK (Santana, 2009). Williams and Pagliari (2004) explore the imbalance in air services among European countries and propose a more centralised administration of and funding for PSOs at the EU level. They believe that such a change could lead to a more efficient and equitable distribution of subsidies and a greater consistency with the broader EU economic, social, and regional development goals (Williams and Pagliari, 2004).

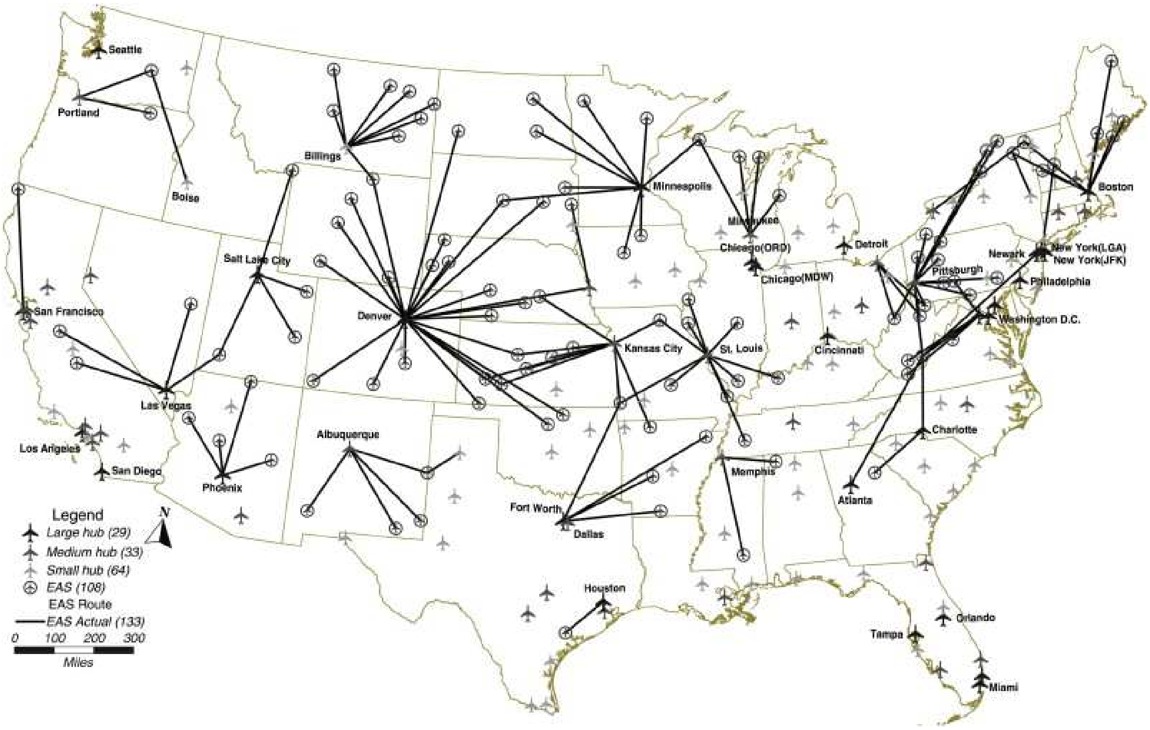


Fig. 2.7 An example of EAS networks in the U.S.

(Adapted from Matisziw et al., 2012)

Apart from sharing a common background, they also share a common purpose—to assure remote areas a minimum of air access—and a common rationale—the economic development of remote areas (Williams and Pagliari, 2004). They also have a common problem: inefficiency. Santana (2009) compares the EAS and PSO to find that ‘airlines under the PSO programme have higher costs but the picture is less clear for the U.S.’. Grubesic and Matisziw (2005) discuss an example of a subsidized flight route between the EAS community of Lewistown, Montana, and its nearest hub airport city, Billings, Montana: ‘During 2006, airfare on this route cost $88 with a 30-day advance purchase on Big Sky airlines. However, the government cost was $1,343 per passenger. According to the US department of transportation, this route averaged two people per day during 2006’ (Grubesic and Matisziw, 2005). They also point out that market coverage is often redundant and suggest alternative definitions of ‘community eligibility’ that would increase programmatic efficiency and reduce federal spending on subsidies (Grubesic and Matisziw, 2011). In addition, Lian and Ronnevik (2011) note the disadvantage of providing subsidies only for local residents. They argue that regional non-residents must pay full fare, restricting the potential for incoming tourism. Inefficiency and ineffectiveness are often discussed as national subsidy programme issues. Studies have analysed operational efficiency within the context of subsidies, but none has assessed which design methodologies were most efficient and effective.

In Japan, national subsidies are limited to flights to remote islands. Matsumoto (2007), looking at commercially unsustainable air transport for remote islands in Nagasaki, points to the importance of governmental subsidies and airport construction for tourism promotion. Moreover, Kato et al. (2011) point out the necessity of subsidies for local airports, arguing that 'airports with more than 5.2 million passengers were profitable when depreciation is taken into account; however, most local airports have fewer than 2.5 million passengers. When depreciation costs are excluded, airports need at least 2.7 million passengers to be viable' (Kato et al. 2011). Their research reveals the necessity of public support in sustaining regional airways with small air traffic demand; however, the existing national programme does not mitigate this problem. As discussed, moreover, anticipated social changes such as population decline and government expansion will prevent regional air transport systems from being sustained through public financing alone.

2.2.4. Symbiotic sustainability of air transportation

Local governments provide special treatment for airlines and passengers in order to sustain regional flights other than those to remote islands. A treatment called 'load factor guarantee' (LFG), for example, attempts to sustain unprofitable regional air transport by considering the market principle. The LFG is an agreement in which airlines and local governments agree to the load factor of a regional flight beforehand, and the government compensates for the difference between the actual and agreed load factors (Hihara, 2007, 20011, 2012). The LFG enables airlines to maintain their load factor above the break-even level, encouraging airlines to enter regional markets where profitability is uncertain. In addition, local governments are encouraged to increase the number of local air passengers to enhance the load factor of regional flights. Thus, the LFG is a policy designed based on ‘commitments’ from both airlines and local government to sustain unstable regional air transport.

Little research on LFG has been done. Fukuyama et al. (2009) analyse the LFG agreement between Tottori Prefecture in Japan and Korea’s Asiana Airline. Their research regards this LFG as a Nash bargaining competition between the airline and the local government and examines the rationality of their negotiation using multivariate regression analysis. The negotiation approximately resulted in a Nash bargaining solution in 2007. Furthermore, they forecast that the load factor would increase as much as 80% in 2010 and that the local government would be required to pay over 100 million JPY for the airline, due mainly to local residents’ reduced utilization of the airport. They conclude that well-integrated public support would be necessary to maintain the unprofitable regional airport. Hihara (2007, 2011, 2012) also analyse the LFG agreement but the case is between Ishikawa Prefecture and Noto Airport in Japan. His researches statistically evaluate the efficiency of the contract under a 1-year setting using mathematical modelling and justify the incentive/risk mitigating payments. But dynamic interactions of the parties are not fully considered in his model. As he mentioned, a multi-year dynamic model would be more realistic (Hihara, 2012).

The integral management of multiple regional airports has recently been discussed. Nomura and Kiritoshi (2010) examine Highlands and Islands Airports Ltd. in Scotland and identify three benefits: 1) economic impact, 2) increased negotiation power, and 3) revenue stability. Uemura and Hirai (2010) argue that the simple integration of currently profitable and unprofitable airports is meaningless since it might hinder the management of losses. The integration of airport management thus has both pros and cons.

2.2.5. Other issues for sustainability of air transportation

Several studies have discussed air transport and disasters both in Japan and in the world. Japan’s use of helicopters and small aircraft has been highlighted since the Kobe earthquake in 1995 and the Niigata Chuetsu earthquake in 2004 (Kumagai and Tahara, 1996; Kobayashi and Tanaka, 2006). Medical aviation is a major concern in disaster-prone countries (Braithwaite, 2001; Epley et al., 2006). Odani et al. (2000) discuss the effective utilization of aircraft to monitor automobile mobility after the catastrophe. My study places greater focus on the management aspect of the air transport system during a catastrophe than on a specific application of air transport, such as for medical treatment.

Managing air transport during a catastrophe was recently discussed by Smith (2010). His argument is that ‘airports are central to the critical national aviation infrastructure and essential to normal economic activities of their regions and even more important after regional disaster and catastrophes’ (Smith, 2010). He examines how regional airports can cooperate and collaborate with local, state, federal, and nongovernmental agencies to promote disaster preparedness, mitigation response, and recovery. Although he interviewed stakeholders from 20 airports in the U.S., his study focuses on airport-to-airport relationships and does not include other regional air transport stakeholders.

Table 2.1 Summary of literature and limitations

	Protective Sustainability	Competitive Sustainability	Parasitic Sustainability	Symbiotic Sustainability
Literature	**45-47 Frame** (Murakami, 1996, Inoue, 2008, Matsumoto, 2007) **Criticize Airport Special Account** (Sasaki, 1986a, Shomi, 1992, Kikuchi, 1999, Kamimura, 2002, Feldhoff, 2002, 2003, Kato et al, 2010, and others)	**Impact study of open sky policy** (Shiomi, 2000, Nakamura, 2008, Barret, 2009) **Efficiency evaluation** (Yoshida, 2004, Yoshida and Fujimoto, 2004, Yamaguchi, 2007, Ozeki, 2008, Kato et al, 2011, Grubesic and Wei, 2012, 2013)	**Criticize national subsidy programs** (Williams and Pagliari, 2004, Grubesic and Matisiw, 2011; Lian and Ronnevik, 2011) **Introduce LCCs** (Barret, 2000; O’Connel and Williams, 2005, Ohshima, 2008, Lei and Papatheodrou, 2010; Castillo -Manzano, 2010, Zhang et al, 2010)	**Load factor guarantee** (Fukuyama, 2009, Hihara, 2007, 2011, 2012) **Integral management** (Nomura et al, 2010, Uemura et al, 2010)
Limitations	• Against open sky policy trends • Not feasible in the long run	• Sustainability for the winners • Ignore removed elements	• Increase public debt • Inefficiency • Geopolitical risk	• Ignore long-term dynamics in business • Qualitative case discussions

2.3. Originality of Research

Following the literature, the conventional approaches to manage unsustainable regional air transport can be divided into two essential trends. The first is the removal of something inefficient from a system to realize healthier management. In this approach, government generally controls on and interventions into the air transport business. Researchers tend to evaluate the productivity of airlines and airports and promoting natural selection through competition. In other words, the approaches aim at competitive sustainability.

The second trend is the survival of a system depending on resources drawn from outside the system. In this approach we found a variety of national subsidy programmes for unprofitable airlines and airport worldwide. In other words, the approaches aim at parasitic sustainability. As I discussed, these sustainability types are limited applicability and effectiveness and not truly sustainable in the long run. Rather, what I would like to propose in this research is symbiotic sustainability. At the best of my knowledge, there is no research that analyses regional air transport system from symbiosis perspectives.

As Brundtland's definition state, sustainability requires consideration of interests of both present and future generations (Brundtland Group, Chapter 2, 1987). It means that business systems must be evaluated throughout its entire life. Lifecycle is a holistic view of considering all phases of an object or a project from its birth to the end of the life. For example in systems engineering, a system lifecycle addresses all phases of its existence to include system conception, design and development, production and/or construction, distribution, operation, maintenance and support, retirement, phase-out and disposal (Blanchard and Fabrycky, p.19, 2006).

The conventional three pillars of sustainability (Environment, Economy, Society) is ossified and not suitable for evaluating sustainability of business system. Thus, I evaluate sustainability of business systems from three different dimensions: 1) Scalability, 2) Stability and 3) Durability (Fig. 1.5). Each of them corresponds to the three fundamental questions for business sustainability: how to grow (Scalability), how to stabilize (Stability) and how to endure (Durability). Scalability is evaluation of how business systems enter and grow in a target market. Stability is evaluation of how to stabilize business systems in maturity stage. Durability is evaluation on business systems regarding how to endure in decay stage. By considering all aspects of these three pillars, we can evaluate sustainability of business systems. In the following, I propose an integrated methodology of systems evaluation for business sustainability and applied technologies.

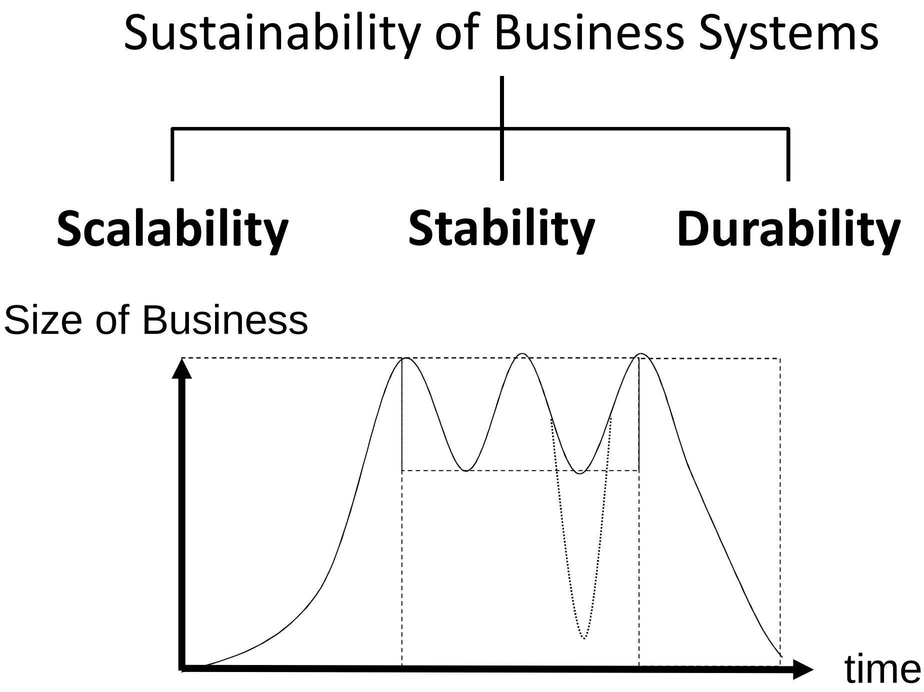


Fig. 2.8 Business Life Cycle Model for Sustainability Evaluation

(Intentionally Blank)

(Intentionally Blank)

Chapter 3. Systems Evaluation Framework and Applied Technologies

Chapter 3 explains the methodology. I fist describe an overview of systems evaluation framework. Then I explain each process of systems evaluation starting from visualization, decomposition and integration, modelling and simulation and decision making. Associated technologies for evaluation are briefly explained in the end.

3.1. Overview of Systems Evaluation Framework

In order to evaluate sustainability of business systems, I introduce systems evaluation in this research. Systems evaluation is based on systems approach that is generally defined as "a holistic multidisciplinary methodology for analysing, evaluating and optimizing a complex system understanding how elements are interacting with each other within a whole system" (Nakano and Minato, 2012). The approach suits to the requirements of interdisciplinary for evaluating sustainability and also can contribute to evaluate long-term, dynamic behaviour of business systems. I divided systems evaluation on business systems into several evaluation components: 1) high-angle visualization of business systems, 2) decomposition and integration of business systems, 3) modelling and simulation of business systems and 4) decision making on business systems. Fig. 3.1 describes an overview of the systems evaluation framework showing the inter-relations of each evaluation component.

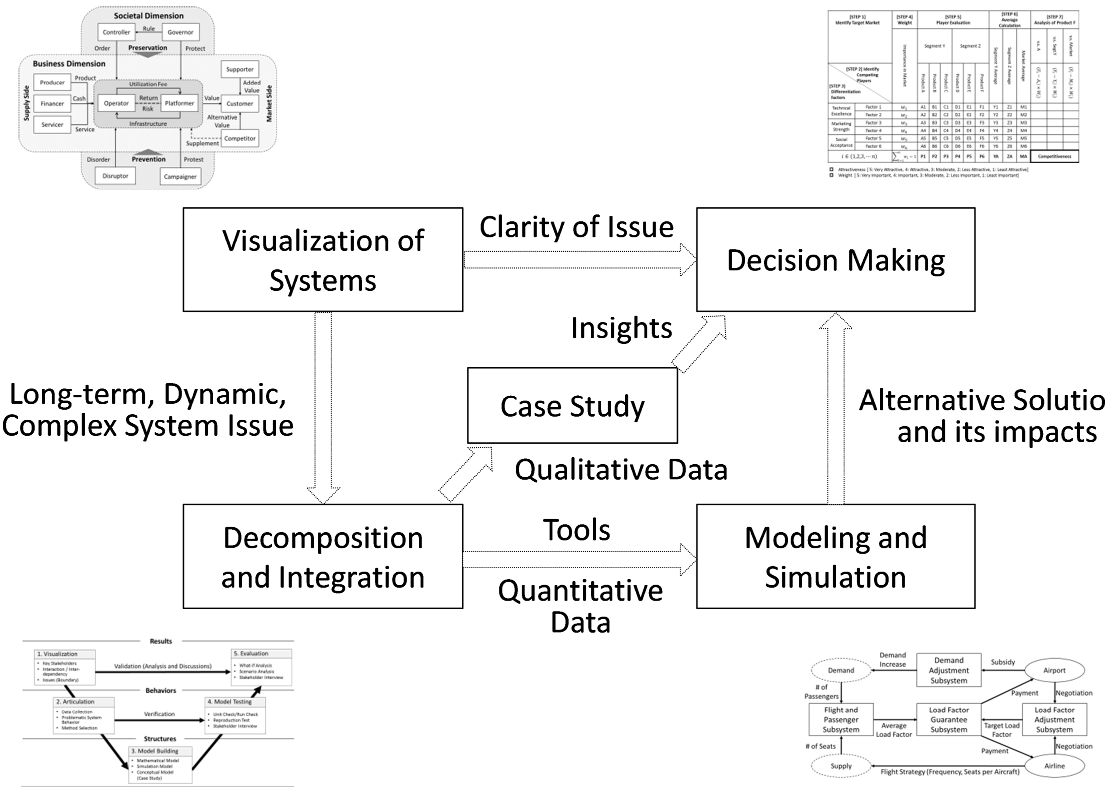


Fig. 3.1 Overview of system evaluation framework

First of all, visualization of systems is conducted for comprehensive understanding on business systems. It provides holistic views on entire business system which allows us to treat all essential issues associated with business systems. When issues of business systems are clearly defined by visualization process, it is able to make decisions considering the goal, options, criteria, requirements and constraints and so on. But when the business systems are associated with long-term, dynamic, complex systems issues, then decomposition and integration is required for detail analysis of business systems. The process divides a huge problem into several sub-problems for more precise analysis and also examines realization of the solution. Considering availability of quantitative data and analytical tools, modelling and simulation is implemented for verification and validation of a proposed system solution. The process can examine effectiveness and efficiency of the solution considering its potential impacts on entire business systems. When quantitative data is not available for evaluation, we can implement case studies on several related business so as to acquire strategic insights on business systems. Decision making is finally conducted before implementing the solution. Matrix operation and Analytical Hierarchy Process are utilized for systematically evaluating alternative solutions from multiple perspectives.

3.2. Visualization of Business Systems

In most of business systems, some stakeholder plays critical roles for running businesses while the others just indirectly support them. It implies that the significance of each stakeholder varies and thus it is important to identify the most inevitable players for sustaining the business systems. Especially in unprofitable business, sustaining all related stakeholders brings about inefficiency of business operations and further aggravation of the profitability. Therefore, I would like to introduce a concept of minimum viable business system (MVBS) and minimum viable business player (MVBP) in this research. MVBS means the combination of minimum elements of players for sustaining business systems. MVBP means the players identified in the scope of MVBS. MVBS and MVBP vary according to the character of business systems, but defining the key concept of a system in the beginning is essential process in systems approach (Nakano and Minato, p.3, 2012). MVBS and MVBP can be selected from several different types of stakeholders. For facilitating the I identification, I classified 12 different types of stakeholders that are associate with business systems generally: 1) Governor, 2) Controller, 3) Platformer, 4) Operator, 5) Producer, 6) Servicer, 7) Financer, 8) Customer, 9) Supporter, 10) Competitor, 11) Campaigner and 12) Disruptor. Each of them is briefly explained and summarized in Table. 3.1.

Governor basically defines rules and regulations. It sometimes provides protections on business systems. Controller plays a role of controlling business systems according to the rules and the regulations. Platformer provides infrastructures that are necessary to operate business systems. Operator manipulates business systems on provided platform using provided resources. Producer supplies products required for operating business systems. Servicer supplies services required for operating business systems. Financer supplies cash resources required for operating business systems. Customer receives values from business system. Supporter provides added value to customer but not holds a direct relation to MVBS. Competitor provides alternative values to customer. Campaigner provides objections and constraints on business systems. Disruptor brings about uncontrollable events on business systems. In most business systems, these stakeholders are interacting with each other for providing a certain value to customers, which in turn, brings about complex behaviours of business systems.

Table 3.1 Classification of Key Stakeholders in Business Systems

Name	Major roles
Governor	Define rules and regulations and provide protection on business systems
Controller	Control business systems according to the rules and the regulations
Platformer	Provide infrastructure to operate business systems
Operator	Manipulate businesses on the provided platform using the provided resources
Producer	Supply products required for business systems
Servicer	Supply services required for business systems
Financer	Supply cashes required for business systems
Customer	Receive values from business systems
Supporter	Not directly related to the business operation but provide added value to customer
Competitor	Provide alternative value to customer
Campaigner	Provide objections and constraints on business systems
Disruptor	Bring about uncontrollable events on business systems

Fig. 3.2 shows a generic model of business systems that I propose in this research. It is consisted of two different dimensions: Business Dimension and Societal Dimension, and MVBS is placed in the centre of the framework. The primal purpose of the framework is to facilitate evaluation of sustainability of MVBS within environments of the business dimension and the societal dimension. The business dimension is further divided into supply side and market side. It covers entire relations of business stakeholders associated with business systems. The societal dimension is also divided into preservation and prevention. Preservation means any influence that aims to sustain business system. For example, governments attempt to sustain business systems especially when the business systems are critically important for society. On the other hand, prevention is any influence that hinders sustainability of business systems. For example, natural disruptions, economic disruption and political disruption prevent business systems to be sustained in a market. Since disruptions are difficult to forecast, they must be carefully managed for sustainability of business systems.

I identified two players as MVBP in this research: Operator and Platformer, and also consider their interactions as MVBS. It is because air transportation is a service-oriented business and it cannot be implemented without operator and platformer. An airline needs airports to provide an air transport service and airports cannot expect any revenue if there is no airline operated there. It implies that these players are systematically dependent on each other within the scope of business systems. I discuss how to manage the relation sustainably overtime.

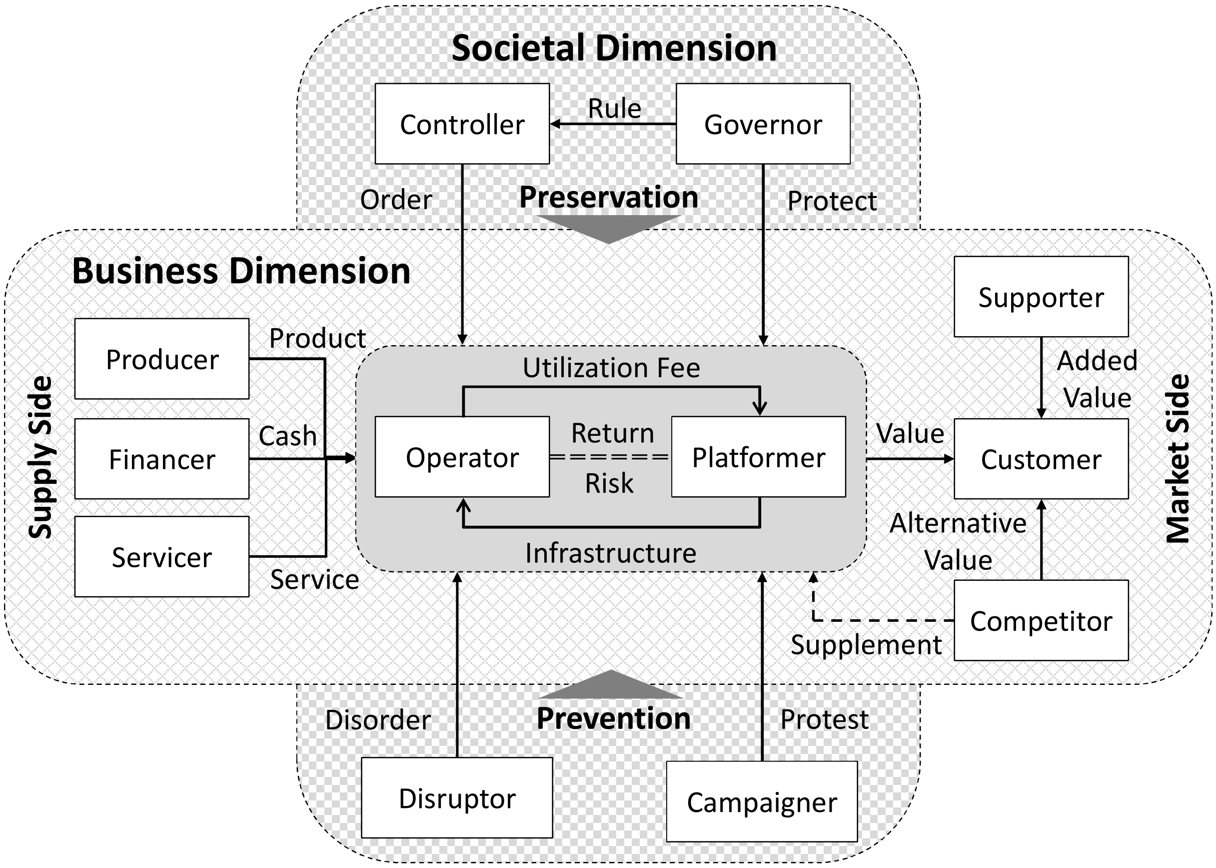


Fig. 3.2 A generic model for visualizing business systems

Fig. 3.3 shows the application of the framework to air transport system. In this case, MVBS is consisted of airline (Operator) and airport (Platformer). They are inevitable players and inter-dependent on each other for sustaining air transport services. In other words, they share the fate of the MVBS. Thus, for sustainability of the MVBS, it is important to balance the benefit and the risk between them in the long run. The benefit means revenues from passengers for airline side and airport charges from airline for airport side. The risk means demand fluctuation as variances in air traffic demand makes it more difficult to manage a commercial air transport service. In such a case, it is worth considering the integration of multiple regional airways that are not individually commercially sustainable. I introduce the portfolio theory drawn from financial analysis to consider ways of reducing business risks by diversifying destinations. I assume that by combining multiple regional airways with different traffic movements, a symbiosis of airline and airport can be designed.

On the other hand, when combining multiple airways is not possible and when future air traffic demand is still uncertain; it is worth considering obtaining a mutual commitment from an airport and an airline to sustainably operate a regional airway. I examine the validity of the load factor guarantee scheme enabling airlines to maintain load factors above the break-even level. The airport is also encouraged to increase the number of air passengers from the local community to increase the load factor. I assume that by committing to a load factor, a symbiosis between an airport and an airline can be designed.

On the supply side of the business dimension, air framers provide the airline with aircrafts. Leasing companies invest money for the aircraft purchase for airline and banks provide cash for operations of the MVBS. Air service providers play supportive roles for aircraft ground handling at airport. Refuel, maintenance, repair overhaul (MRO) are included there. When these players provide products and services to the MVBS, the primal concern for sustainability is its competitiveness in a target market. In other words, they would like to evaluate competitive advantage of themselves inside the market. Systematic approach is required for such evaluation. On the demand side, passengers receive from the MVBS as air transport service. Local communities support the passengers by providing accommodations, restaurants and sightseeing. They are not directly connected with operation of the MVBS but provide value-added services to it. Ground transport is basically a competitor to the MVBS providing alternative high speed transport service to passengers. However, they become servicers supplementing the MVBS. For example, local ground transport such as train, bus and taxi, provide passengers with ground access measures to airport. Such ground public transport system enhances value of the MVBS. Furthermore, high speed trains and buses usually compete with air transport for acquiring passengers but they can support with each other at the time of catastrophic natural disasters (Minato and Morimoto, 2012). These competition with the other measures of transport is evaluated by travel time and travel cost. Systems evaluation method is required there.

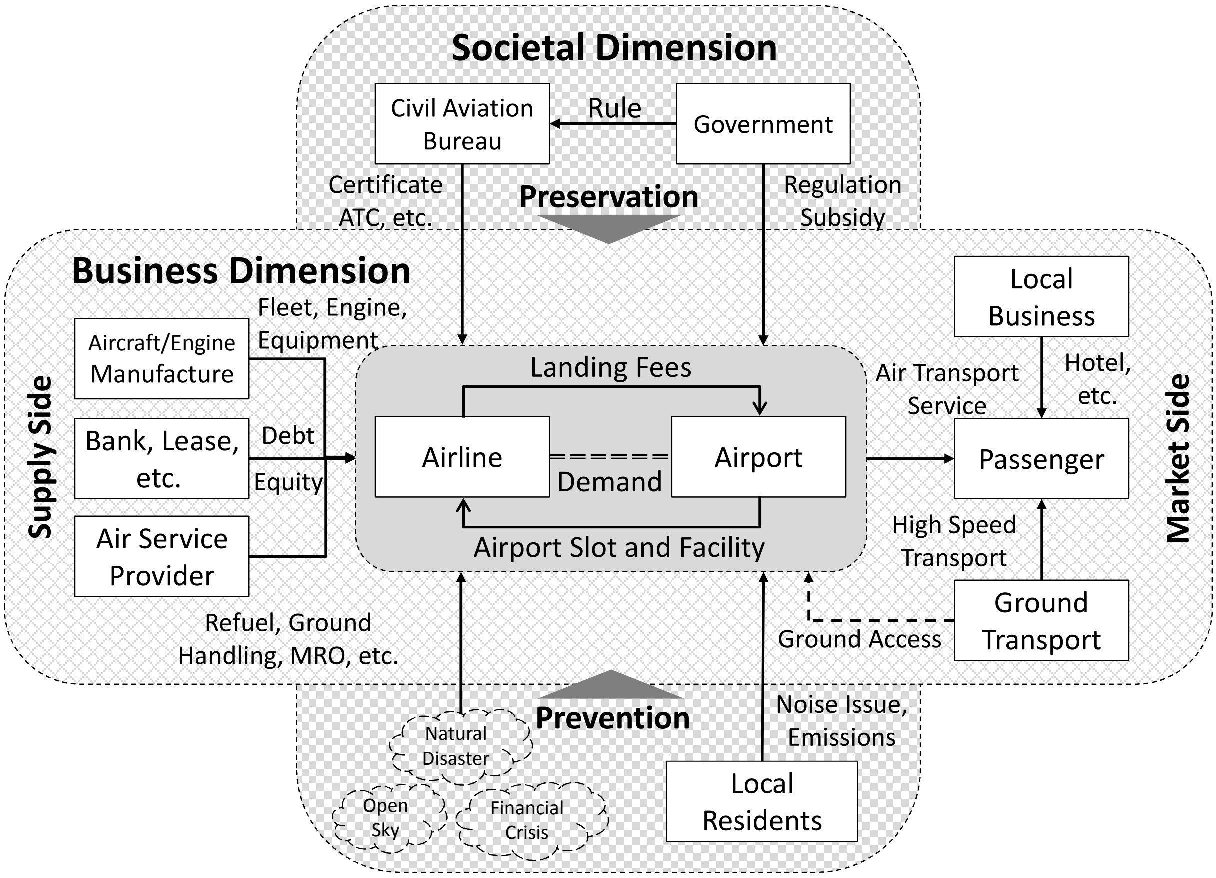


Fig. 3.3 Application of the Framework to Air Transport System

The MVBS is also surrounded by the societal dimension (Fig. 3.4). Governments are major players who are willing to preserve the MVBS since they have interests in it. They set rules and regulations on air transport for healthier management of the system such as airport and aircraft restrictions. Japan Civil Aviation Bureau (JCAB) control Japanese air transport system according to the rules. It provides air traffic control to airline and airport. Type certificate (TC) and air worthiness are also its responsibility. Above all, the most important role of government is to provide subsidy for sustaining regional air transport system. When air traffic demand is expected to decrease in the long run, subsidy is one of measures to sustain the business system. Ecosystem concept can be introduced for effective and efficient design of the subsidy programs.

On the other hand of the societal dimension, there is disruption. I identified catastrophic disaster as natural disruption, financial crisis as economic disruption and open sky as political disruption. Open sky is an agreement which provide operational freedom of air transport services between two countries. It implies new entry of foreign airline and thus is threats to domestic airlines. In this research, I focus on discussing management of regional air transport during a catastrophic natural disaster. This was added after the East Japan earthquake and tsunami of March 11, 2011. Managing demand fluctuation and thinness is essential for the long-term commercial sustainability of a regional air transport system, but disaster management is also critical for the short-term operational sustainability of the system. During disruptive events such as catastrophic natural disasters, the commercial management of regional air transport is not an issue. On the contrary, integrating air transport even with other means of transport is critical for coping with the drastic expansion of tentative traffic demands such as rescues and evacuations. Considering ways to co-exist with Japan’s frequent natural disasters will help make the regional air transport a more sustainable system.

3.3. Vee Model of Decomposition and Integration

The next evaluation component applied is decomposition and integration. It aims to divide a huge problem into several sub-problems for more precise analysis and also examines realization of the solution. Vee model (Fig. 3.4) is used to “visualize the system engineering focus, particularly during the Concept and Development Stage. The Vee highlights the need to define verification plan during requirements development, the need for continuous validation with the stakeholders, and the importance of continuous risk and opportunity assessment” (INCOSE SE Handbook ver.3.2, p. 27, 2010).

Fig. 3.6 shows the evaluation process applied in the framework. The left side represents decomposition process and the right side represents integration process and the entire vee represents a life cycle of problem solving activities. It implies that the activities proceed from the left-hand side to the right-hand side as time lasts. The model is consisted of five steps: 1) Visualization, 2) Articulation, 3) Model Building, 4) Model Testing, and 5) Evaluation.

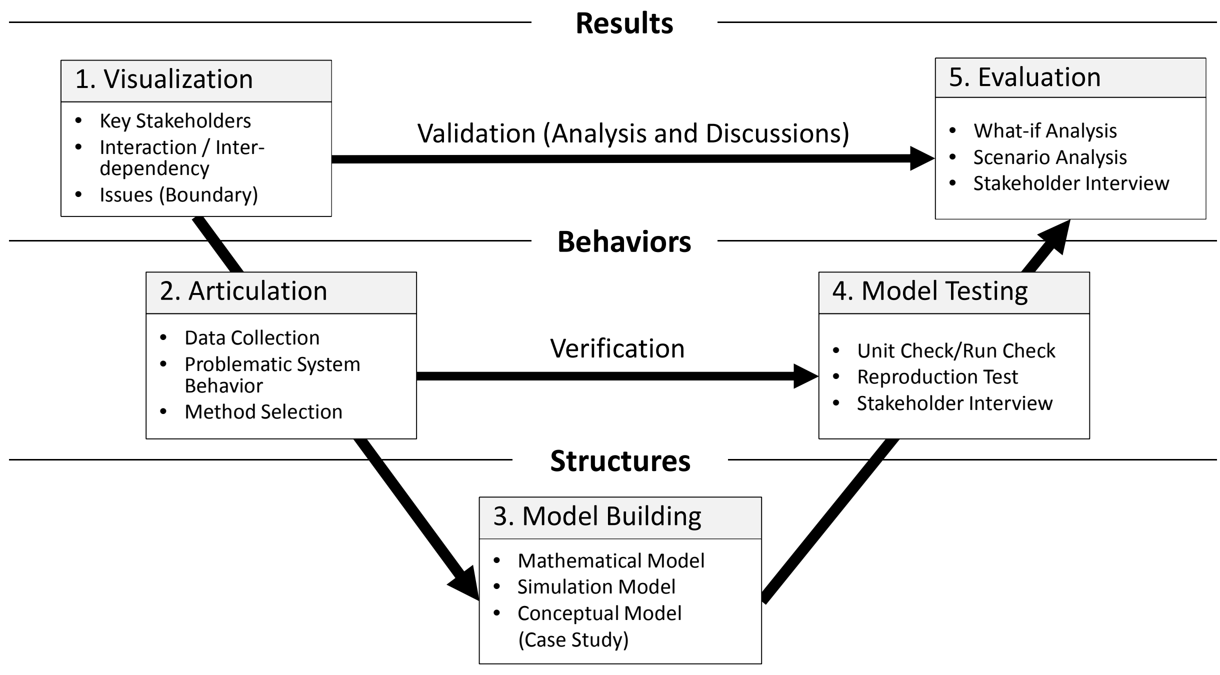


Fig. 3.4 Vee Model for Decomposition and Integration

As discussed in Ch.1, I proposed to analyze business systems based on its systems structure. Therefore, I integrated the vee model process with three hierarchical layers: Results, Behaviors and Structure. Visualization and Evaluation are on the results layer. Articulation and Model Testing are on the behaviors layer. Model Building is on the structure layer. It clearly illustrates business systems are evaluated based on the structures which in turn brings about the behaviors and results in the end.

The first step is Visualization. It starts with visualizing business systems using the proposed generic model (Fig. 3.2). The most important is to identify key stakeholders and define MVBS and MVBP. The primal purpose of systems evaluation is therefore to examine sustainability of the MVBS considering its interactions with the environments of business dimension and societal dimension. Purpose of the evaluation should be considered in the beginning considering issues and system boundary.

The second step is Articulation. It requires collecting both quantitative data and qualitative data for systems evaluation. Government statistics, survey and questionnaire, interviews are often utilized. Problematic system behavior is identified in this process. Then we need to select method that is appropriate for evaluation. Quantitative and qualitative methods are both available according to the purpose.

The third step is Model Building. When quantitative data is available and the purpose of evaluation requires to specific quantitative results, then we should use mathematical modeling or simulation modeling. Both require a certain amount of knowledge for utilizing each method. When a problem is not appropriate for quantitative data analysis or quantitative data is unlikely to be available, then we need to consider qualitative methods. Developing a conceptual model or case study approach is generally utilized. The case study approach does not always guarantee reproducibility of evaluation results but it sometime provides deep insights on complex business systems on the basis of stakeholder interviews.

The forth step is Model Testing. This is manly for mathematical modeling and simulation modeling. We need to check the consistency of the model unit and run the simulation for examining its functionality. Data reproduction test is often utilized for verification of the model. Verification is defined as “confirmation, through the provision of objective evidence, that the specified requirements have been fulfilled” (INCOSE SE Handbook ver.3.2, p. 363, 2010). In business systems evaluation, it checks that the model can appropriately reproduce the behaviors of business systems in reality. Coefficient of determination (R squire), MAE (Mean Absolute Error) and MAPE (Mean Absolute Percentage Error) are utilized for statistical verification of the model. When case study is applied, stakeholder interviews can be used for verification.

The fifth step is evaluation. We often use sensitivity analysis, what-if analysis, scenario analysis and Monte-Carlo simulation for this purpose. Sensitivity analysis means a parametric study of a variable to an objective function. What-if analysis rather focuses an impact of a change in one variable on an objective function. Scenario analysis considers combination of multiple variables and its impact on an objective function. Monte-Carlo simulation includes consideration of uncertainty associated with variables. Probabilistic distribution is given for multiple rounds of computer-aided simulation. Validation is required in this stage. It is defined as "confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled" (INCOSE SE Handbook ver.3.2, p. 363, 2010). In business systems evaluation, it analyzes and discuss that the visualized and articulated problem is really solved.

3.4. Modeling and Simulation

3.4.1. System Dynamics modelling

I regard regional air transport as a multi-stakeholder system in which airlines, airports, aircraft, local governments, and local communities mutually and dynamically interact to bring passengers from an origin to a destination. As a dynamic analysis is required for an understanding of the complex behaviour aroused by the multi-stakeholder interactions, I mainly use system dynamics (SD) in this research (Fig. 3.5). System dynamics is a method of modelling the nonlinear dynamics of complex systems developed by Jay Forrester of MIT in the 1950s (Sterman, 2000, Nakano and Minato, pp. 79-88, 2012). The SD methodology is divided into two categories: 1) System thinking and 2) Modelling and Simulation.

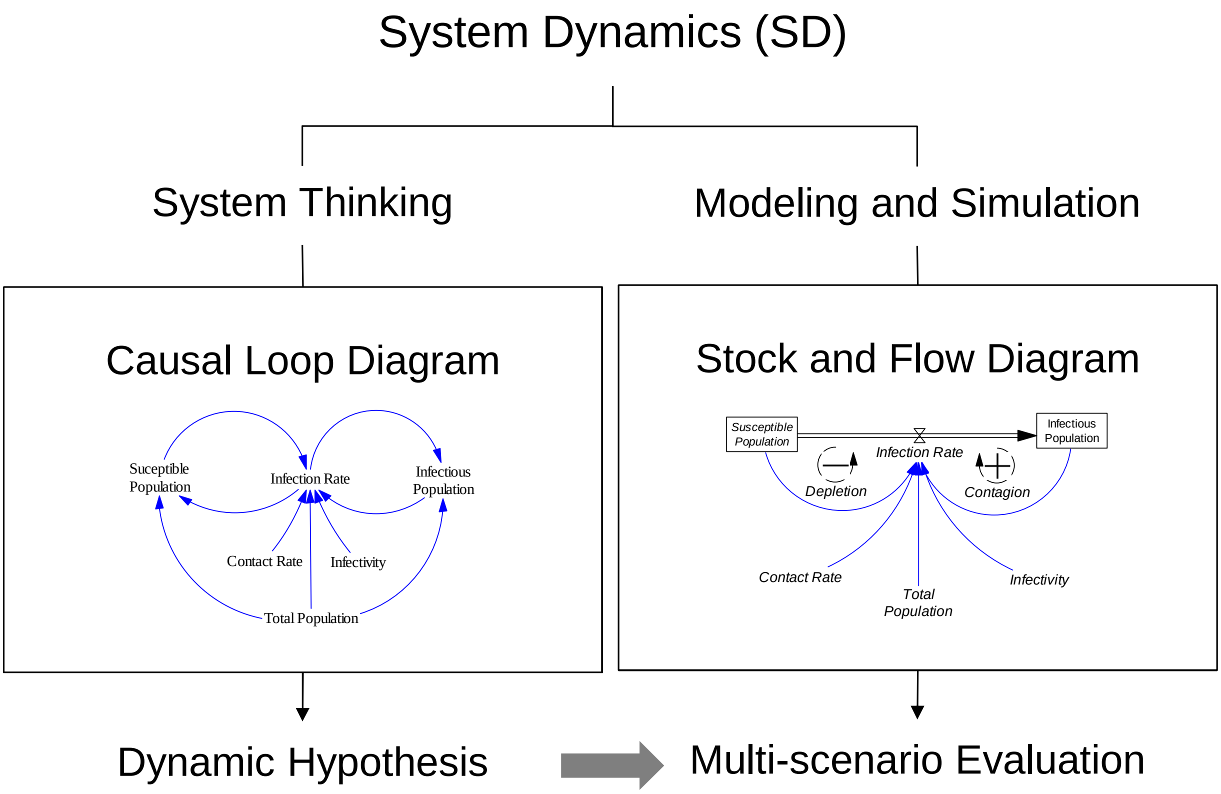


Fig. 3.5 System Dynamics Approach

System thinking is an effective measure to decompose a system into its elements using multiple variables so as to analyse its structure and behaviour. A Causal Loop Diagram (CLD) is a tool used to display the structure. It consists of variables connected by arrows denoting the causal influences among the variables. (Sterman, p138). Fig. 1.14 shows an example of CLD analysing influences of advertisement. A part of profit is invested for advertisement and it contributes to increase sales volume and then increase revenues. The feedback cycle on the left is a positive effect on profit. On the other hand, investment on advertisement substantially requires cost increase and thus it decrease profit in the end. This feedback cycle on the left is a negative effect on profit. The CLD helps to understand dynamic behaviour of system overtime. In other words, a dynamic hypothesis can be formed with CLD regarding how the problematic behaviour is generated within a system (Sterman, pp. 94-105).

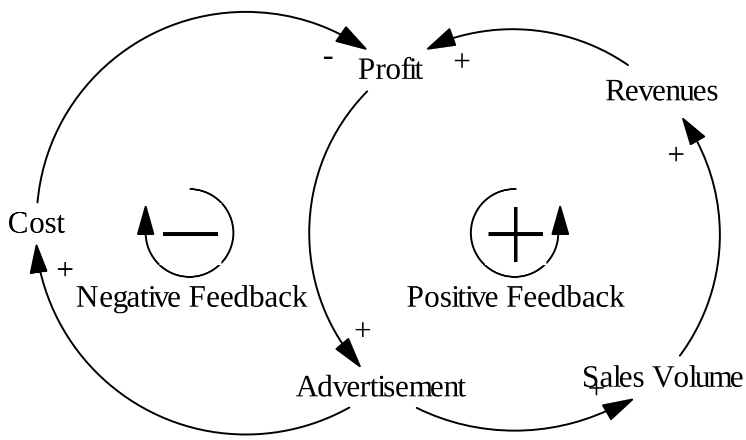


Fig. 3.6 Causal Loop Diagram (CLD)

After setting a dynamic hypothesis using CLD, it is necessary to build a model using a Stock and Flow Diagram (SFD) according to the simulation purpose (on the right in Fig. 1.12). It uses several graphical icons, such as stock, flow, valve, and cloud icons, to express a system (Fig. 3.6). Stocks are integrated accumulations of inflows and outflows. Inflows are represented by pipes leading into a stock and outflows by pipes leading out. Valves in the middle of each pipe control the inflows and outflows. Clouds represent the sources, and sinks represent the flows (Sterman, pp. 192, 2000). SFD enables to understand different behaviours of a system according to different scenarios. The graphical notation (Fig.3.6) facilitates not only to model but also to understand a complex system in a simple manner. Software such as Vensim, Stella, Powersim and AnyLogic are generally utilized for SD modelling today. In this research, I mainly utilize Vensim (Chapter 5 and Chapter 6) and AnyLogic (Chapter 10).

Fig. 3.7 Stock and Flow Diagram (SFD)

For mathematical modelling, System Dynamism uses both integral equation (Eq. 3.1) and deferential equation (Eq. 3.2). Assume now that state of system is represented by Stock (t) and calculated by:

$$\text{Stock (t)} = \int_{t_0}^{t} [Inflow(s) - Outflow(s)]ds + Stock\ (t_0)$$

Eq. (3.1)

where t_0 is initial time, t is terminal time, inflow is a flow connected into to the Stock and outflow is a flow connected out from the Stock. Deferential of Stock at time t is then calculated by;

$$\frac{d(Stock)}{dt} = Inflow\ (t) - Outflow\ (t)$$

Eq. (3.2)

Regional air transport displays complex behaviour due to the dynamic interactions among its multiple stakeholders (see Fig. 1.15): ‘Airports encompass a number of operational and commercial processes, with inherent complexities in their management and coordination phases' (Jarach, pp. 1, 2005). System dynamics facilitate the examination of the behaviour within such a complex ecosystem when the interests of regional and national economies impede the performance measurements of airports through more conventional methods (Humphreys and Francis, 2002b).

Several scholars have used SD to study air transport management. Lyneis (2000) uses SD models to forecast aircraft demand. Miller and Clarke (2007) use SD models to evaluate strategies for investment in aviation infrastructure. Suryani et al. (2010) formulate an SD model for simulating the expansion of passenger terminal capacity and forecasting passenger demand, relying on SD's 'capability of representing physical and information flows, based on information feedback controls that are continuously converted into decisions and action' (Suryani, Chou, and Chen, 2010).

3.4.2. Portfolio Modelling

I introduce portfolio theory from financial analysis for quantitatively evaluating effectiveness of risk diversification. Diversification eliminates unique risk, but there is market risk that diversification still cannot be eliminated (Brealey et al., 2006). Individual stock holds its own risk according to the characteristic of business. There are also common market-wide risks that influence all stocks in the same market. The former is called as unique risk or unsystematic risk and the latter is called as market risk or systematic risk. Theoretically speaking, the more variety of stocks combined in a portfolio, the less risk it holds due to the diversification effect (Fig. 3.8). I introduce this concept of portfolio modelling for evaluating regional airway combinations.

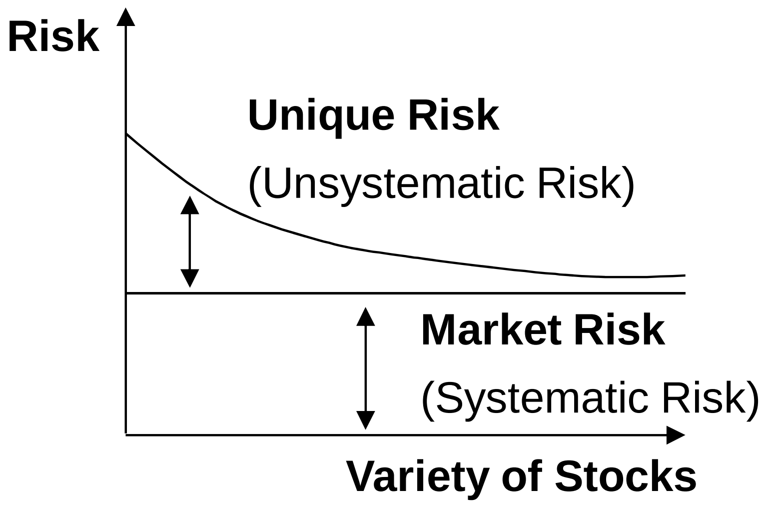


Fig. 3.8 Unique risk and market risk

The idea of financial β is used for representing the risk of individual stock as sensitivity to the market average movement. I assume that movement of air traffic demands would be consisted of two different fluctuations, 1) unique fluctuation and 2) market fluctuation. Unique fluctuation is dependent on each airway's individual characteristics such as size of population, tourist, passengers, and hotel capacity and so on. On the other hand, market fluctuation is caused by market-wide seasonality and holiday structures which affect the whole country equally. The point is that "diversification eliminates unique risk. But there is some risk that diversification cannot eliminate. This is called market risk" (Brealey et al. P165). As securities in a market, unique fluctuation represents unique risk which can be reduced by diversification. On the other hand, market fluctuation represents market risk which cannot be reduced even by diversification. The β is calculated as in Eq. (3.3),

$$\beta = \frac{Cov\ (f_i\ ,\ f_m)}{Var\ (f_m)}$$

Eq. (3.3)

where Cov (f_i, f_m) is the covariance between the demand fluctuation of individual airway and the air traffic demand fluctuation of market average. Var (f_m) is the variance of the demand fluctuation of the market average. β indicates the sensitivity of individual demand fluctuation to market-wide demand fluctuation. For example, when β is greater than 1.0, then it is expected to "amplify the overall movement of the market" (Brealey et al. p167). On the other hand, when β is between 0 and 1.0, then it is expected to "move in the same direction as the market, but not as far" (Brealey et al. p167). The point is that "risk of a well-diversified portfolio is proportional to the portfolio beta, which equals the average beta" (Brealey et al. 2006) of all airways included in the portfolio. Therefore, I calculate the risk of well-diversified portfolio of multiple airways as 'Portfolio β' as in Eq. (3.4),

$$\text{Portfolio } \beta = \frac{Cov\ \left(f_p\ ,\ f_m\right)}{Var\ (f_m)}$$

Eq. (3.4)

where Cov (f_p, f_m) is the covariance between the demand fluctuation of airways portfolio and the demand fluctuation of market average. Var (f_m) is the variance of the demand fluctuation of market average. The variance of the portfolio is calculated as in Eq. (3.5),

$$\text{Variance of Remote Isand Portfolio} = \sum_{i=1}^{N}\sum_{j=1}^{N}(x_i\, x_j \sigma_{ij})$$

Eq. (3.5)

where the number of airways in portfolio is N, and x_i is the proportion of the resource investment.

3.4.3. Analytical Hierarchy Process (AHP)

Systems evaluation requires strategic decision making at the end of its process. Strategic decision can be defined as defining objectives and selecting the best answer from multiple alternatives under insufficient and uncertain information (Nakano and Minato, 2012). It implies that the final decision making should also be evaluated using systems approach.

I introduced analytical hierarchy process (AHP) for the purpose. It is an evaluation method combining subjective judgement and systems approach (Ikeda et al., 2011). It enables to make a decision on multiple alternatives according to multiple criteria and the decision structure can be visualized in three layers: Goal (Top), Criteria (Middle) and Alternatives (Bottom) as shown in Fig. 3.8.

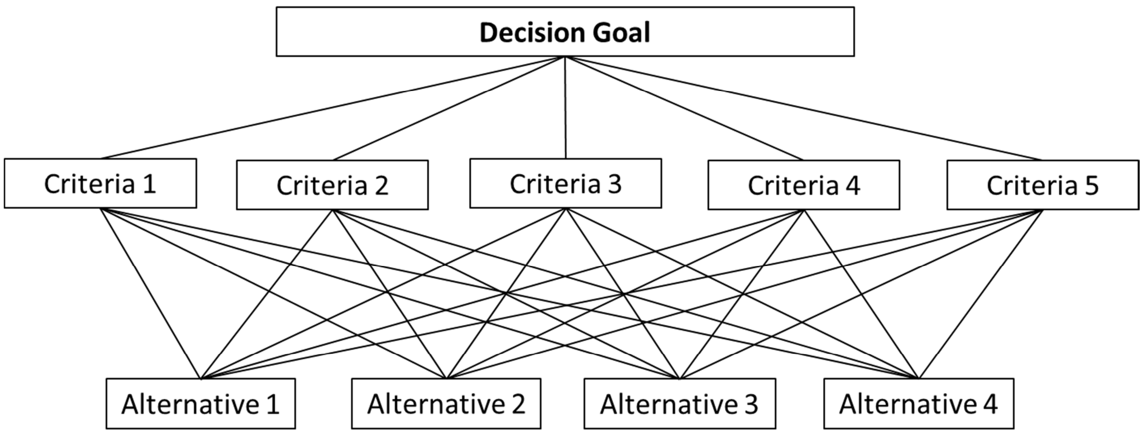


Fig. 3.9 Structuration of decision making with AHP

The first step is to define a goal of decision making. Then we consider multiple criteria that are necessary for the decision. These criteria are evaluated with pairwise comparison. It is a mean to compare two different items individually and provide evaluations according to a certain quantitative scale. Table 3.2 illustrates an example of pairwise comparison matrix. By comparing an item on the left and one on the right, I put either score of 9 (extremely good), 7 (very good), 5 (moderately good), 3 (fairy good) or 1 (neutral) for one side and its inverse number for the other side. The importance of each evaluation criteria is examined using pairwise comparison seeking the geometric mean of the pairwise comparison matrix and then the normalized results. The normalized result means the relative weight of each criterion. Then we need to each alternative according to each criterion with pairwise comparison matrix. The consistency index should be calculated in Eq. 3.6 for examining the consistency of each pairwise comparison (Ikeda et al., 2011).

$$\text{Consistency Index (C.I.)} = \frac{\lambda_{max} - n}{n - 1}$$

Eq. (3.6)

where λ_{max} is Eigen Value of the Pairwise Comparison Matrix and n is the number of items included in the Pairwise Comparison.

Table 3.2 Pairwise Comparison Matrix

	Extremely Good		Very Good		Moderately Good		Fairly Good		Neutral		Fairy Good		Moderately Good		Very Good		Extremely Good	
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Item (Left)																		Item (Right)

(Intentionally Blank)

PART 2

Stability of Business Systems

(Intentionally Blank)

Chapter 4. Airline-Airport (Multiple Airways)

In Part 2, Chapter 4 and Chapter 5, I discuss stability of business systems. Chapter 4 mainly considers the challenge of airline and airport for managing air traffic demand fluctuation assuming there are multiple airways (Fig. 4.1). It means that there are multiple airports in a specific region and multiple airways are possible to be operated. As air traffic demand variance makes it more difficult to manage a commercial air transport service, I use the portfolio theory drawn from financial analysis to look at ways of reducing the business risks of regional air transport by diversifying destinations. Air transport to remote islands is the most difficult case to commercially manage, so I examine remote island flights in Japan.

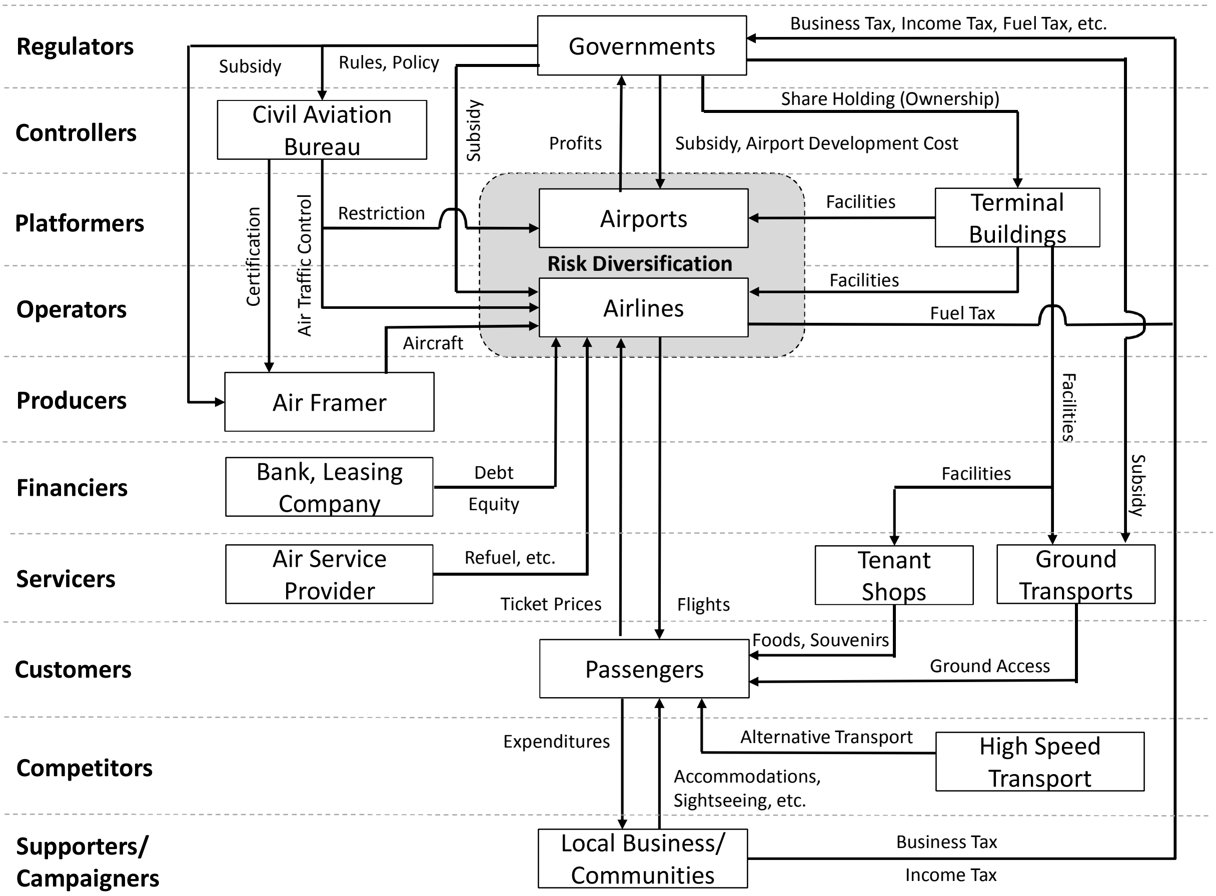


Fig. 4.1 Scope of Chapter 4 (Risk diversification between Operator and Platformer)

4.1. Chapter Introduction

Remote island economies often depend on tourism as it can play an important role in spurring investments in new infrastructure, stimulating other industries, generating employment, and increasing income on the islands (Warnock-Smith and Morrell, 2008), but remote islands are, by definition, distant from the main sources of tourist demand and thus rely on air transport. Commercial flights to remote Japanese islands suffer from thin markets and fluctuations in demand; the average traffic flow to islands is often less than 25% of that for inter-city flights on the mainland, and the load factor of remote island flights is 7% lower (Matsumoto, 2007). Many airports on these islands do not service scheduled flights, limiting tourism and the mobility of local residents. To stimulate services, low or zero landing fees are common, and some local governments provide subsidies to airlines (Uemura andHirai, 2010, Yai and Hashimoto, 2011.). This requires maintaining a flow of public finance to support air services and makes managing the regional air transport system difficult.

I have designed a method for reducing reliance on public monies and apply it to 31 airports on remote Japanese islands. As the large variances in market structures make it difficult to manage air transport systems to remote islands, I use the portfolio theory to consider ways of reducing business risks by diversifying the portfolio of multiple flight destinations. The methodology is applied to some of Japan's 6,852 remote islands, about 400 of which are inhabitable. There were 98 public airports in Japan as of April 2012, 35 of which are located on remote islands (JCAB, 2012).

The remainder of this chapter is organized as follows. The section 4.2 explains the data used for systems evaluation. The section 4.3 explains the methodology highlighting the system evaluation process and mathematical modelling for Island β anaysis. The section 4.4 presents several analyses—the principle component analysis, the cluster analysis, and the Island β analysis. The section 4.5 discusses the results. The section 4.6 provides the conclusions and identifies the study's limitations.

4.2. Data for Systems Evaluation

Data from Remote Island Statistics (National Institute of Japanese Islands (NIJI), 2007) covering April 2005 to March 2006 are used in the analysis. Of the 35 remote island airports in Japan, I focus on 31 (see Table 4.1). The other four are excluded because of either an interruption or elimination of commercial flight operations during the period. The analysis considers six variables: the population of the island, the annual tourists to the island, the annual air passengers to the island, the annual seaborne passengers to the island, the hotel capacity on the island, the island's dependency on air transport; the share of visitors to the island coming by air. As the alternative to flying is arriving by boat, combined air and sea traffic comprise the denominator.

Table 4.1 Data for 31 remote islands

Airport	Population	Annual Tourists	Annual Air PAX	Annual Naval PAX	Hotel Capacity	Air Transport Dependency
Minami-Daitou	1,331	3,800	35,029	1,700	154	95.4%
Kerama	53	4,400	2,272	201,700	995	1.1%
Tarama	1,397	6,200	35,352	3,500	137	91.0%
Kita-Daitou	515	7,700	19,851	1,500	85	93.0%
Hateruma	588	14,300	3,564	57,000	214	5.9%
Ojika	2,813	16,700	3,092	87,700	148	3.4%
Aguni	912	19,900	13,177	30,600	216	30.1%
Kikai	8,610	26,000	81,004	42,500	416	65.6%
Amakusa	4,619	30,200	73,410	177,100	452	29.3%
Yonaguni	1,677	31,700	76,447	4,700	492	94.2%
Kouzushima	2,141	32,000	13,675	30,200	1,615	31.2%
Niijima	2,559	43,400	22,671	101,400	1,611	18.3%
Okinoerabu	14,419	50,600	94,395	82,200	1,425	53.5%
Okushiri	3,686	52,500	11,678	122,000	1,118	8.7%
Yoron	5,752	66,100	67,149	61,800	2,131	52.1%

Hachijojima	8,673	82,700	213,050	33,900	2,594	86.3%
Kumejima	9,118	93,900	254,299	46,600	1,259	84.5%
Tokunoshima	27,621	116,600	39,918	118,800	762	25.2%
Kamigotou	23,327	151,000	4,671	209,700	1,033	2.2%
Ohshima	8,945	211,400	68,864	419,300	3,335	14.1%
Fukue	41,282	219,600	162,550	666,100	2,120	19.6%
Iki	32,342	231,500	28,893	672,600	3,823	4.1%
Tsushima	39,193	289,900	311,548	327,600	1,861	48.7%
Yakushima	13,724	333,900	173,90	443,500	1,240	28.2%
Miyako	48,347	413,500	1,055,963	547,200	5,186	65.9%
Oki	23,809	432,800	44,813	844,400	4,154	5.0%
Rishiri	5,926	449,400	31,461	459,000	696	6.4%
Tanegashima	34,056	516,300	111,655	511,100	2,506	17.9%
Sado	67,917	674,500	9,917	1,871,600	9,910	0.5%
Amami	68,245	678,700	595,582	397,800	1,693	60.0%
Ishigaki	46,399	754,200	1,914,129	2,063,300	8,348	48.1%

Table 4.2 provides descriptive statistics of the six variables used in the analysis. It is likely that not all the variables are normally distributed, with mean values being larger than the median values. The coefficient of variation calculations gives air passenger the highest score, indicating a relatively high variation compared to the other variables. In fact, the skewness and kurtosis for air passengers are both high, making an extreme value in air passengers likely. Furthermore, although the coefficients of the variation for annual tourists and hotel capacity are the same, the kurtosis for hotel capacity is much higher than that for annual tourists, meaning the former is likely to include an extreme value, increasing the degree of variation within the data. This suggests that some remote islands have a character extremely different from that of the others.

Table 4.2 Descriptive statistics for the 31 airports

	Population	Annual tourists	Air passengers	Sea passengers	Hotel capacity	Air transport dependency
Minimum	53	3,800	2,272	1,500	85	0.01
Maximum	68,245	754,200	1,914,129	2,063,300	9,910	0.95
Median	8,673	82,700	44,813	122,000	1,259	0.29
Mean	17,742	195,335	179,806	343,165	1,991	0.38
Std. Dev. (n-1)	20,134	226,471	385,275	493,687	2,300	0.33
Skewness (Pearson)	1.18	1.16	3.49	2.38	2.09	0.51
Kurtosis (Pearson)	0.33	0.13	12.13	5.37	4.13	-1.13
Confidence Interval (95%, lowest)	10,357	112,265	38,486	162,079	1,147	0.26
Confidence Interval (95%, highest)	25,127	278,406	321,126	524,250	2,835	0.50
Coefficient of Variation	113%	116%	214%	144 %	116%	85%

4.3. Methodology

4.3.1. Systems evaluation process

Fig. 4.2 shows the systems evaluation process applied in Chapter 4. The descriptive statistics indicate that some remote islands have extremely different characteristics. Principle component and clustering analyses are used to handle this by categorizing the airports into groups with relatively homogeneous characters in terms of tourism and transportation.[1] Then, I introduce Island β to analyse the inherent risk of tourist demand fluctuations for each island. The model is tested with the case of Japan Air Commuter (JAC). A portfolio of multiple remote islands is examined to find strategic ways of managing unprofitable regional air transport in the end.

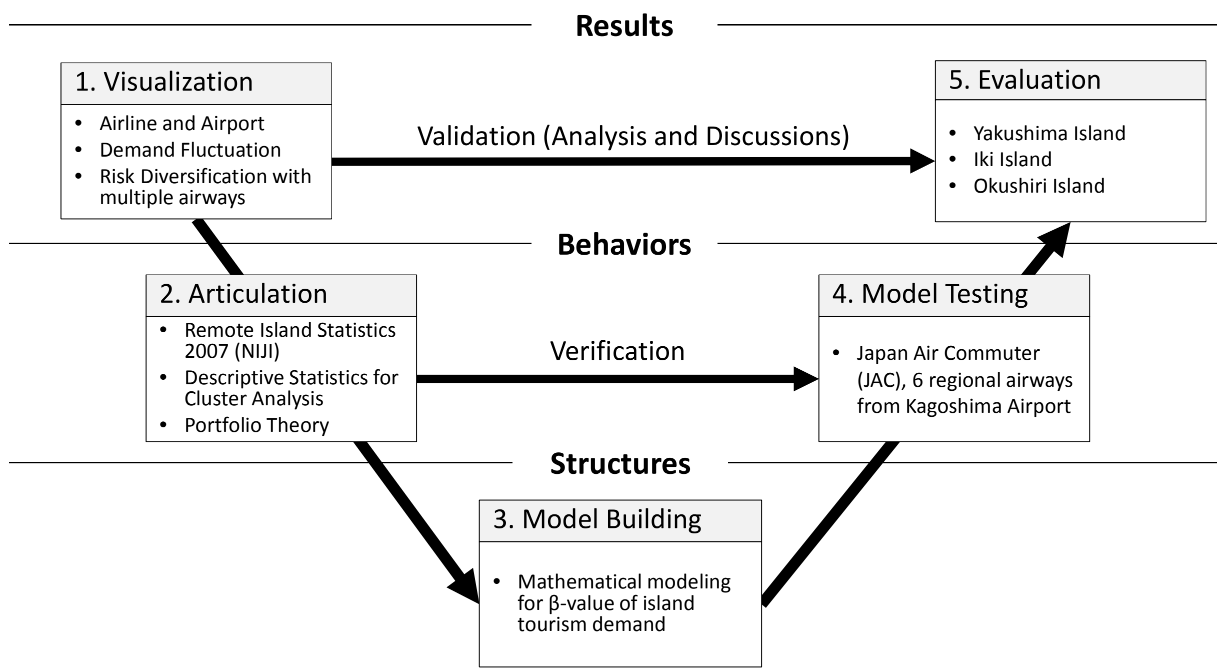


Fig. 4.2 Process of the research in Chapter 4

[1] In the principle component analysis, all factors with eigen values greater than one are retained as significant, but all values with a factor loading above 0.5 are also included as significant.

4.3.2. Mathematical Modelling of Island β

The notion of Island β is used to describe the inherent risk of tourist demand fluctuations on each island. The idea is similar to financial β, which represents a stock's sensitivity to the market's average movement. It is assumed that the movement of tourism demand on remote islands consists of two types of fluctuations—unique fluctuation and market fluctuation. The former is dependent on each island's individual characteristics, such as population, tourists, passengers, and hotel capacity. Market fluctuation is caused by market-wide seasonality and holiday patterns that affect the whole country. The financial analysis assumes that diversification eliminates unique risk but that there is a market risk that diversification cannot eliminate. As in the financial market, unique fluctuation represents unique risk that can be reduced by diversification and market risk that cannot be reduced. Island β is calculated as,

$$\text{Island } \beta = \frac{Cov\ (f_i, f_m)}{Var\ (f_m)}$$

Eq. (4.3)

where Cov (f_i, f_m) is the covariance between the fluctuations in tourist demand for individual remote islands, *i* and the overall fluctuation in the market average demand, *m*, and Var (f_m) is the variance in the tourism demand fluctuation of the market average. Island β indicates the sensitivity of individual island tourism demand fluctuation to market-wide volatility. For example, when Island β is greater than unity, it is expected to amplify the overall movement of the market, but when it is between zero and one, it is expected to move in line with the market.

A well-diversified portfolio of multiple remote islands as Portfolio β can be defined as,

$$\text{Portfolio } \beta = \frac{Cov\ (f_p, f_m)}{Var\ (f_m)}$$

Eq. (4.2)

where Cov (f_p, f_m) is the covariance between the tourism demand fluctuation of remote island portfolio p and the tourist demand fluctuation of market average m, which is calculated for the 31 remote islands, and Var (f_{m}) is the variance of the tourism demand fluctuation of the market average. The variance of the remote island portfolio islands is thus,

$$\text{Variance of Remote Island Portfolio} = \sum_{i=1}^{N}\sum_{j=1}^{N}(x_i x_j \sigma_{ij})$$

Eq. (4.3)

where the number of remote islands in the portfolio is N, and x_i is the proportion of the resources invested.

4.4. Analysis

4.4.1. Principle component analysis

Table 4.3 presents the result of the principle component analysis, where the eigenvalues indicate the degree of the variables' influence; for example, the eigenvalue for Factor 1 is 3.865 and accounts for 64.4% of the total variance. Given the combined explanatory power of Factors 1 and 2 (84.1%), these are used in the analysis. Table 4.4 presents the factor loadings of each variable for these factors; those exceeding 0.5 are adopted.

The first dimension based on Factor 1 is 'Tourism Economic Size'. Most of the variables, other than Dependency on Air Transport, show relatively high factor loading scores on that dimension, and all those variables are closely related to the size of the tourist economy: the higher the score for Factor 1, the greater the size of the tourist sector on the island. For the second dimension based on Factor 2, Annual Air Passenger and Dependency on Air Transport had relatively high factor loading scores, implying that the higher the score on Factor 2, the greater the dependency on aircraft for transportation to the island, either for tourism or business.

Table 4.3 Principle component analysis (PCA)

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Eigenvalue	3.865	1.185	0.422	0.325	0.148	0.055
Variation (%)	64.4%	19.7%	7.0%	5.4%	2.4%	0.9%
Accumulation (%)	64.4%	84.1%	91.1%	96.6%	99.0%	100%

Table 4.4 Factor loading

	Factor 1	Factor 2
Population	0.866	
Annual tourists	0.927	
Annual air passengers	0.702	0.541
Annual seaborne passengers	0.943	
Hotel capacity	0.908	

Dependency on air transport	0.934

4.4.2. Cluster analysis

Hierarchical clustering methods were used to determine the best number of airport clusters. The results suggest a four-cluster solution for the data, with significant differences between them. In addition, ANOVA tests indicate that both factors contributed to the differentiation of the four airport clusters, supporting the appropriateness of the categorization. Fig. 4.3 illustrates the distribution of the clusters, and Table 4.5 gives the mean values of each factor for each cluster.

Table 4.5 Cluster analysis (mean value of each factor of each cluster)

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Factor 1	-1.128	-0.326	3.865	5.229
Factor 2	1.030	-0.786	1.613	-1.771

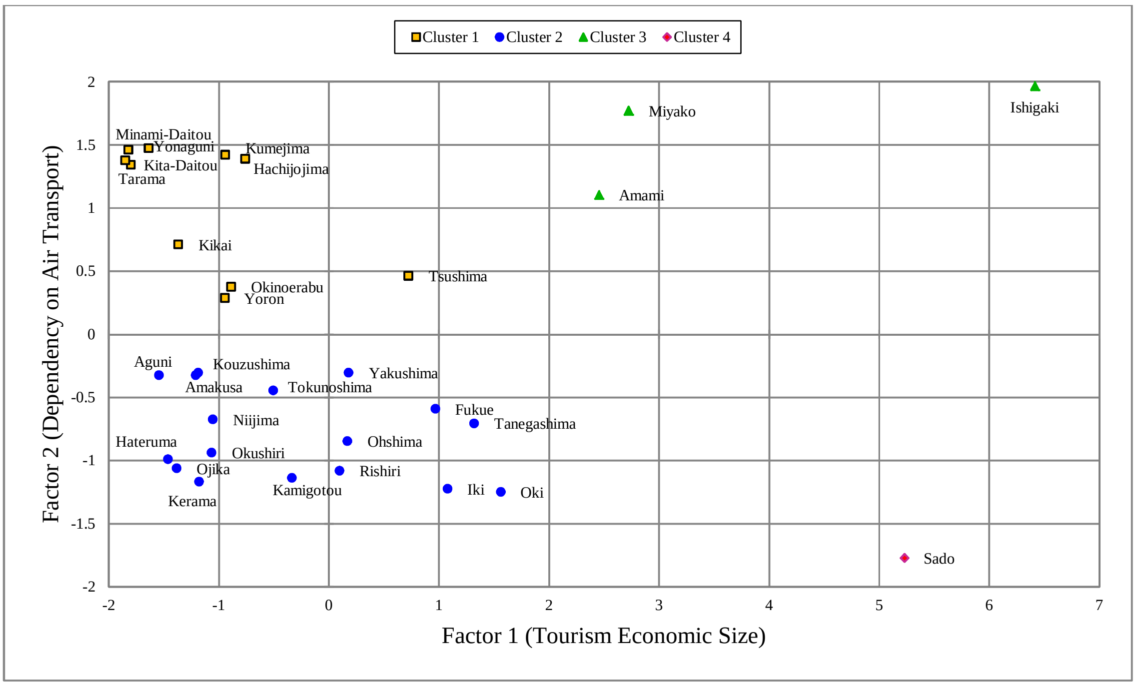


Fig. 4.3 Result of cluster analysis

- Cluster 1 includes ten airports and has the lowest mean score for Tourism Economic Size and the second highest for Dependency on Air Transport among the clusters. It is called ‘Small tourism dependent on air transport’.

- Cluster 2 includes 17 airports and has the second lowest mean score for Tourism Economic Size and the second lowest mean score for Dependency on Air Transport. It is thus called ‘Small to medium tourism dependent on sea transport’.

- Cluster 3 consists of three airports and appears to have the second highest mean score for Tourism Economic Size and the on Dependency on Air Transport. It is therefore called ‘Large tourism dependent on air transport’.

- Cluster 4 includes only one airport and has the highest mean score for Tourism Economic Size and the lowest mean score for Dependency on Air Transport among the four clusters. It is thus called ‘Large tourism dependent on sea transport’.

Three airports are excluded from Cluster 3 (Ishigaki, Miyako, and Amami), and one is excluded from Cluster 4 (Sado), partly because their characteristics are so different from those of the other airports.

The results of the principle components and cluster analyses provide several insights into the links between remote island air transport and tourism in Japan. First, when tourism is a relatively small part of an economy, the scale of air transport is irrelevant, but tourism is affected by the lengths of an island’s runways. There are nine airports in Cluster 1 and ten in Cluster 2 with negative Factor 1 scores. The average runway length of the nine Cluster 1 airports is 1,583 m and 1,030 m for the ten Cluster 2 airports (see Table 4.6). When tourism increases slightly (Factor 1= 0 to 2.0), transport tends to depend on shipping more than on aircraft. There is only one airport in Cluster 1, however, and seven in Cluster 2 when Factor 1 is 0 to 2.0, with the average runway length in the latter being 1,775 m (see Table 4.7), much longer than the average runway length in Cluster 1, with Factor 1 less than zero and where tourism is less important. Therefore, runway length does not seem to be a critical factor in air transport to remote islands when there are large numbers of tourists.

Table 4.6 Runway length (Airports with a Factor 1 of less than 0)

Cluster 1 Airports (Factor 1<0)	Runway Length (m)	Cluster 2 Airport (Factor 1<0)	Runway Length (m)
Yoron	1,200 m	Aguni	800 m
Kikai	1,200 m	Kerama	800 m
Okinoerabu	1,350 m	Hateruma	800 m
Minami-Daitou	1,500 m	Ojika	800 m
Kita-Daitou	1,500 m	Niijima	800 m
Tarama	1,500 m	Kouzushima	800 m
Yonaguni	2,000 m	Kamigotou	800 m
Kumejima	2,000 m	Amakusa	1,200 m
Hachijojima	2,000 m	Okushiri	1,500 m
		Tokunoshima	2,000 m
Average (n=9)	1,583 m	Average (N=10)	1,030 m

Table 4.7 Runway length (Airports with a Factor 1 of 0 to 2.0)

Cluster 1 Airports (Factor 1= 0 to 2.0)	Runway Length (m)	Cluster 2 Airport (Factor 1= 0 to 2.0)	Runway Length (m)
Yonaguni	2,000 m	Ohshima	1,800
		Tanegashima	2,000
		Oki	2,000
		Rishiri	1,800
		Fukue	2,000
		Yakushima	1,500
		Iki	1,200
		Average (N=7)	1,775 m

4.5. Results and Discussions

Island β was estimated for each of the islands in Clusters 1 and 2 for the sample of 27 islands after recalculating the variances (see Table 4.8). For the 'Small tourism dependent on air transport' islands, all ten islands had Island β values of between zero and one, suggesting some sensitivity to overall market fluctuations, as their tourism sectors (except Tsushima) may be relatively small.

Table 4.8 Results of Island β analysis (Cluster 1 and Cluster 2)

Cluster	Name (Island and Airport)	Value of Island β
1	Minami-Daitou	0.04
1	Kita-Daitou	0.06
1	Yoron	0.07
1	Yonaguni	0.09
1	Tarama	0.12
1	Okinoerabu	0.28
1	Kikai	0.32
1	Kumejima	0.34
1	Hachijojima	0.39
1	Tsushima	0.81
2	Aguni	-0.05
2	Kerama	0.00
2	Hateruma	0.00
2	Ojika	0.00
2	Ohshima	0.09
2	Niijima	0.12
2	Tanegashima	0.31
2	Amakusa	0.40
2	Oki	0.47

2	Tokunoshima	0.78
2	Kouzushima	0.78
2	Kamigotou	0.80
2	Rishiri	1.35
2	Fukue	1.48
2	Yakushima	2.32
2	Iki	5.36
2	Okushiri	9.12

There are large variances in Island β for 'Small to medium tourism dependent on naval transport' islands: it is between zero and one for some and exceeds unity for others, indicating sensitivity to large market fluctuations. This may be attributed to the diversity of the scale of tourism in the cluster. For example, the minimum was Aguni and the maximum was Oki. Furthermore, some islands, such as Yakushima, Iki, and Okushiri, have extreme tourism characteristics. Since the commercial air transport risk on these islands is likely to be high, they may be useful examples of where diversification can be productive.

First, because Yakushima is located in southwest Japan, in Kagoshima prefecture, and Tanegashima, Tokunoshima, Kikai, Okinoerabu, and Yoron airports are relatively close, a portfolio embracing these six remote islands, Portfolio (A), is assumed. I calculate the variance in the remote island portfolio in Eq. 5 and calculate portfolio β in Eq. 4. The results for Island β are shown in Table 4.9. The Island β of Portfolio (A) is 0.53, much lower than the Island β for Yakushima alone, suggesting that the risks of tourism demand fluctuation can be diversified by designing portfolio (A) out of multiple remote islands.

Secondly, Iki is also located in the southwest, in Nagasaki prefecture, with Tsushima, Ojika, Kamigotou, Fukue, Amakusa, and Oki serving as potentially cooperating airports. We thus assume a portfolio comprising these seven islands, including Iki; this is Portfolio (B). The Island β of 1.03 is again lower than the Island β of Iki alone, indicating that the risk of tourism demand fluctuation may be reduced by designing portfolio (B) by diversifying across the associated multiple remote islands. It is thus possible to reduce risk down to almost market level by designing a portfolio.

Finally, Okushiri is located in northeast Japan, in Hokkaido, with only Rishiri relatively close. A portfolio of the two remote islands, Portfolio (C), is assumed. I find that Island β of Portfolio (C) is almost half of Island *β* of Okushiri alone, indicating that the risk of tourism demand fluctuation is significantly reduced through a portfolio of services based on these islands. Nevertheless, the Island *β* measure is still high, and a certain degree of risk remains.

Table 4.9 Island *β* analysis of island portfolio

	Variance f_i or f_m	Covariance $f_{i,}$ f_m	Island β
Yakushima	1,177,829,167	400,440,202	2.32
Portfolio (A)	88,306,366	92,257,701	0.53
Iki	5,509,093,333	926,778,548	5.36
Portfolio (B)	338,097,075	178,899,815	1.03
Okushiri	16,408,836,667	1,576,402,016	9.12
Portfolio (C)	5,325,029,167	712,992,685	4.13
Market	172,784,655	172,784,655	1.00

Finally, using Island *β*, the prospects of using portfolio adjustments to reduce air transport risk can be examined. As I presented above, the Island β of Portfolio (A) is 0.53, much lower than the Island β for Yakushima alone (2.32), suggesting that the risks of tourism demand fluctuation can be diversified by designing a portfolio. Data from Japan Air Commuter (JAC), which operates the six island flights in Portfolio (A) originating from Kagoshima, the regional hub airport, are used for the examination.

Fig. 4.4 shows the number of air passengers per month from April 2005 to March 2006 in Portfolio (A) and confirms that Yakushima, with a standard deviation of 3,510, had the widest fluctuations. To adjust to the considerable fluctuations in Yakushima-bound traffic, JAC varied the number of flights per month, providing 414 flights in August but only 266 in June. With a portfolio of islands, JAC could optimally manage its fleets among the islands and increase its load factor. Fig. 4.5, showing the load factor for Portfolio (A), displays the stabilization. The maximum load factor for Yakushima was originally 77.5% and the minimum 46.2%, making a 31.3% difference; under Portfolio (A), however, the respective figures are 71.0% and 51.1%, for a difference of only 19.9%, and the other standard deviation is only 6.0.

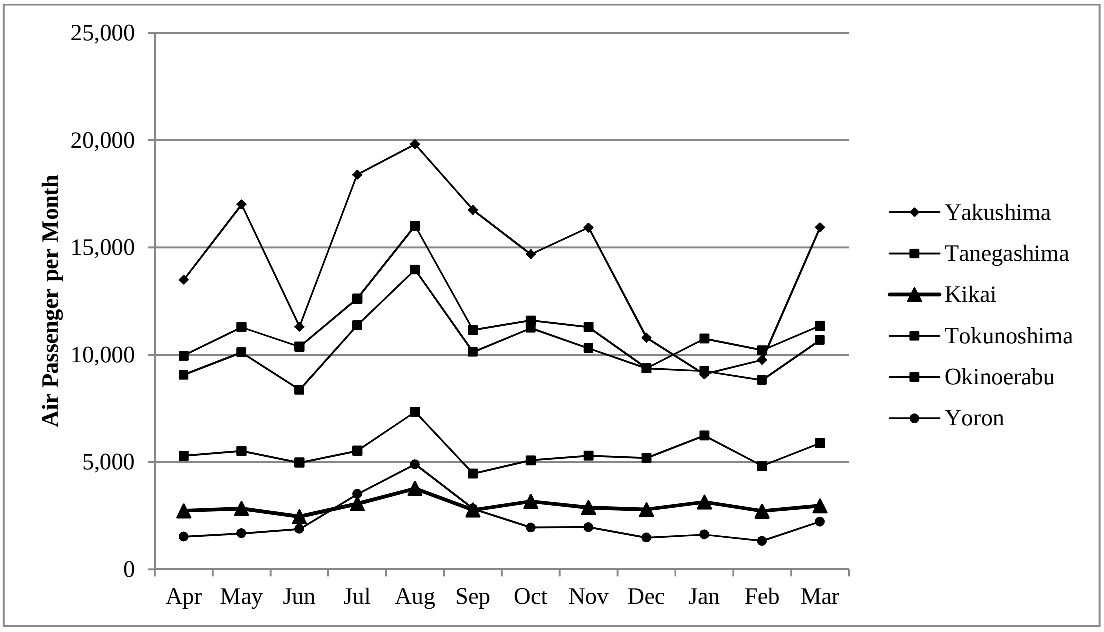


Fig. 4.4 Air Passengers per Month in Portfolio (A)

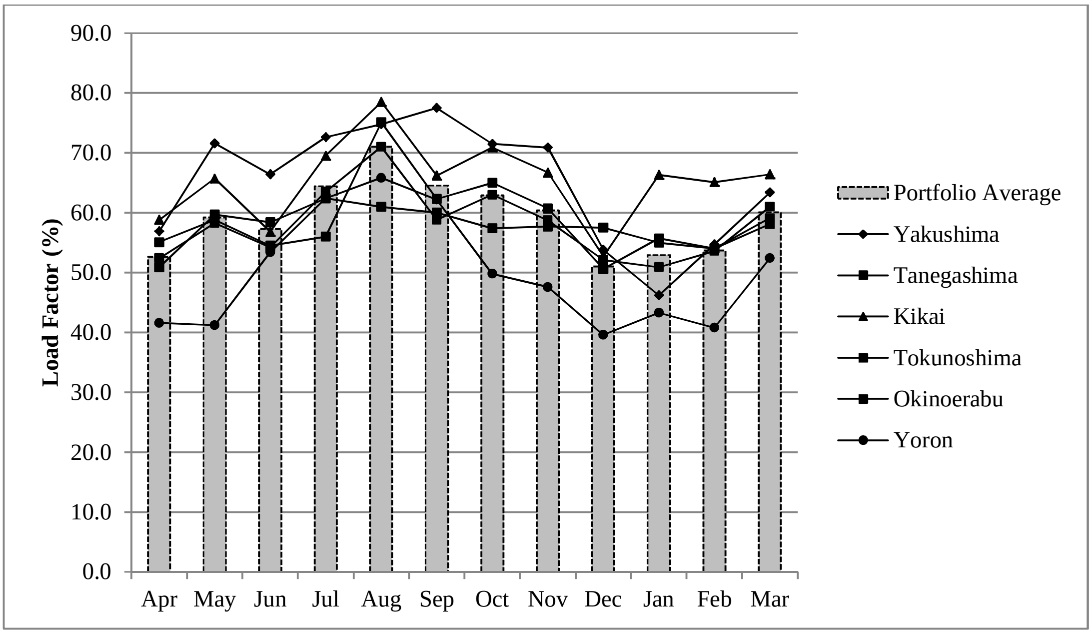


Fig. 4.5 Load Factor of Portfolio (A)

Source: Ministry of Land, Infrastructure, Transport and Tourism (2006)

4.6. Chapter Conclusions

This chapter discussed symbiotic sustainability of airline and airport when there are multiple airways. I introduced the portfolio theory drawn from financial analysis to help reduce the business risk of supplying air transport to remote Japanese islands with significant fluctuations in travel demand. The Island β concept expressed the risk demand fluctuation associated with each remote island. Calculations showed that a well-diversified portfolio of multiple remote islands allows airlines to reduce the commercial risks associated with temporal variation in demand. A more stable market should both reduce the costs of providing air services and allow them to contribute more fully to the tourism industries of Japan's remote islands.

The proposed methodology can be applied when there are multiple regional airways with varying demand movements and thus do not address the unprofitability of a single airway. Thus, the following chapter deals with how to effectively manage demand fluctuation between airline and airport for a single regional airway. I examine a regional flight service to a peninsula where both the population and economy are quite small.

(Intentionally Blank)

Chapter 5. Airline-Airport (Single Airway)

In Chapter 5, I also discuss how to sustain airline-airport relation. But in this chapter I focus more on the challenge of managing a single airway (Fig. 5.1). This reflects the problem of how to sustain a flight to Tokyo from local city airport (see 1.4.1). The previous chapter examined possibility of risk diversification with multiple airways while this chapter examines risk and return sharing between an airline and an airport. I highlight an air transport service to a peninsula far away from the mainland, where air transport, rather than ground transport, plays an essential role. Managing a commercial flight to a peninsula is difficult, due mainly to the thinness of demand caused by the low population density.

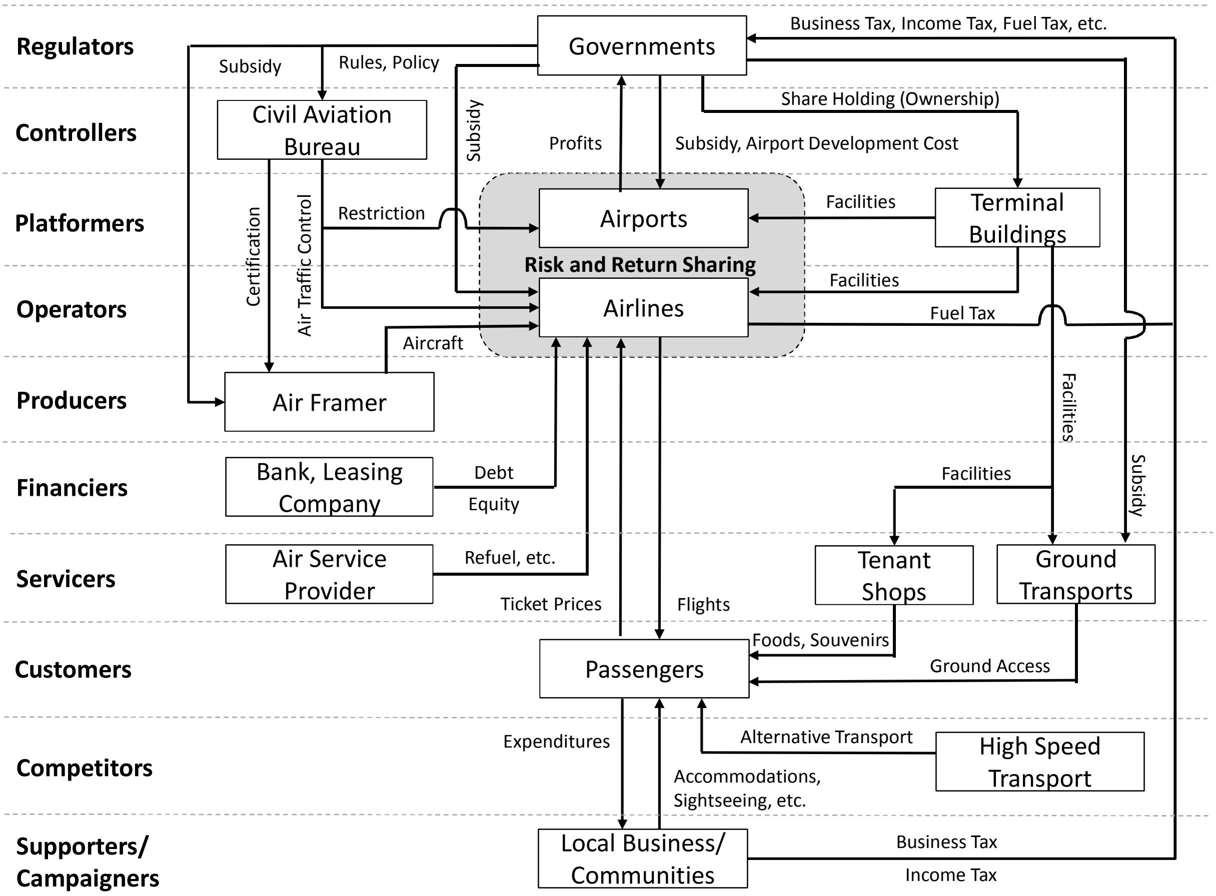


Fig. 5.1 Scope of Chapter 5 (Risk and return sharing between Operator and Platformer)

5.1. Chapter Introduction

Regional air transport generally has a thin air traffic demand with wide fluctuations; thus, its operational efficiency is lower than that of trunk routes (Suzuki et al., 1995). Critical factors in enhancing the profitability of regional air transport include fleet selection and daily frequency (Sato et al., 1990). However, at the micro level, forecasting future air traffic demand is imprecise (Lyneis, 2000), adding to an airline's difficulties when making decisions and developing a new regional airway.

To reduce the business risk associated with the entry of a new regional airway, governments provide financial support when air travel demand is expected to be slight and when air transport is important to local livelihoods and economies (Minato and Morimoto, 2011a). Measures such as profit loss compensation, landing fee reductions, and fuel tax reductions are then made available (Nomura and Kiritoshi, 2010). However, these measures do not essentially mitigate the problem. Furthermore, as discussed, anticipated social changes such as population decline and larger governments will prevent Japan's regional air transport system from relying solely on public financing.

Here, I elaborate on a new management scheme, the load factor guarantee (LFG), which attempts to mitigate business risk and may be able to manage the profitability of airways based on market principles (Fig. 5.2). More concretely, LFG is an agreement by which an airline and an airport, usually owned by a local government, agree to the load factor of a regional flight beforehand. The airport and government then compensate for the discrepancy between the actual and the agreed-upon load factor. An airline may transfer a portion of its revenues to a local government when the actual load factor is higher than the guaranteed load factor (Noto Airport Promotion Council [NAPC), 2012). The LFG allows airlines to maintain load factors above the breakeven level and therefore encourages airlines to enter regional air routes even when profitability is uncertain. In addition, the local government is encouraged to increase the number of local air passengers to enhance the load factor of a regional airway. With this contract, there are two scheduled flights a day between Noto airport and Haneda airport (530 km away) provided by ANA group (mostly by A320 with 166 seats), and ticket prices range from approximately 20,000 yen ($160) to less than 10,000 yen ($80) (Hihara, 2012).

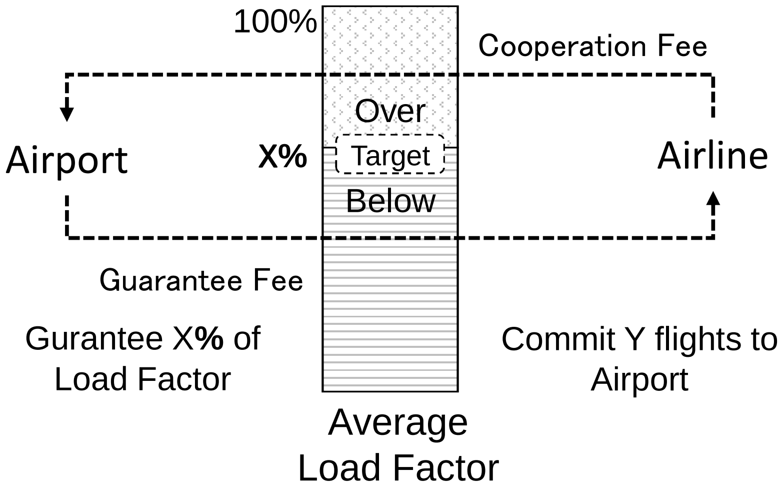


Fig. 5.2 Load factor guarantee scheme

Few studies on LFG have been done; therefore, the validity of the management must be appropriately studied. Hihara (2007) analyses the LFG agreement between Ishikawa Prefecture and ANA (Fig. 5.2). His study attempts to forecast future load factor and pay-off considering the impact of the LFG agreement on both parties' decision-making, but the results are not significant due to data scarcity. Fukuyama et al. (2009) analyse the LFG agreement between Tottori Prefecture in Japan and Korea's Asiana Airlines. Their research considers LFG as a Nash bargaining competition between airlines and the local government and examines the rationality of the negotiations using multivariate regression analysis. The negotiation resulted in an approximate Nash bargaining solution in 2007. However, these studies analyse the LFG using mathematical modelling with static data input and do not consider the dynamic interactions among stakeholders, which could greatly affect the future state of the LFG.

Therefore, I would like to examine the validity of a LFG scheme by analysing the feedback effect of each stakeholder's decision-making on long-term airline-airport coexistence. The remainder of this chapter is organized as follows. The section 5.2 explains the data used for systems evaluation. The section 5.3 illustrates systems evaluation process and overview of the model structure. The section 5.4 explains the details of the System Dynamics model. The section 5.5 describes the results of model testing. The section 5.6 presents the analysis and discussions based on the simulation results. The section 5.7 provides the conclusions and identifies the study's limitations.

5.2. Data for Systems Evaluation

I used data for the Haneda–Noto flight, believing the case to be appropriate for a simulation for two key reasons. First, the Haneda–Noto route has operated from Noto Airport since it opened and thus provides a complete stream of uninterrupted data. Second, the prefecture government owns and manages the airport and has supported ANA and passengers through a LFG. This particular LFG requires ANA to operate twice-daily flights between Haneda and Noto. Whenever average load factors are below the guaranteed threshold, the prefectural government compensates ANA for the difference. When the load factor exceeds the guaranteed load factor, ANA transfers some revenues to the prefectural government. These agreements have sustained the twice-daily flights since the airport opened in 2003. Table 1 shows the flight and passenger records (NAPC 2012).

For this particular LFG, both parties agreed on a maximum payment amount and ranges around the guaranteed load factor, making both parties exempt from payments since 2005 (Fukuyama et al., 2009; Minato and Morimoto, 2011b, Hihara, 2012). In 2005, for example, the target load factor was 64%. However, the government had to pay ANA only when the actual load factor was below 63%, and ANA had to pay the government only when the load factor exceeded 65% (NAPC, 2010). The model excluded the maximum payment and the ranges around the guaranteed load factor in order to present a more generalised simulation model of a LFG.

Table 5.1 Historical Haneda–Noto flight data (NPAC, 2012)

	2005	2006	2007	2008	2009	2010	2011
# of Seats in A/C	166	166	166	166	166	166	166
# of Passengers	160,052	156,945	158,558	150,365	148,768	132,698	149,093
Seats Provided	240,575	241,195	242,517	241,437	239,294	237,705	240,350
Average LF	66.5%	65.1%	65.4%	62.3%	62.2%	55.8%	62.0%
Target LF	64%	62%	62%	62%	62%	62%	62%

Table 5.2 Monthly passenger demand (NPAC, 2012)

	2005	2006	2007	2008	2009	2010	2011
Jul	12993	13,037	12,598	13,938	12,704	12,780	12,050
Aug	16,370	16,738	15,443	14,612	14,073	14,258	15,149
Sep	12,252	12,141	13,809	12,853	12,405	11,420	13,222
Oct	13,501	14,393	12,394	12,289	12,063	13,371	13,766
Nov	13,321	13,770	13,379	11,711	11,833	12,246	13,342
Dec	13,418	13,054	13,587	12,384	12,244	10,047	11,680
Jan	12,525	13,026	12,166	12,885	11,577	10,752	9,816
Feb	11,645	12,804	11,844	11,661	11,235	10,913	10,560
Mar	15,511	12,776	13,288	13,443	13,209	9,348	11,314
Apr	10,516	10,406	10,253	10,901	9,680	7,237	9,883
May	14,521	11,421	14,711	12,589	13,725	10,792	12,761
Jun	13,920	13,016	14,906	10,811	14,418	10,162	14,593

5.3. Methodology

5.3.1. Systems evaluation process

Fig. 5.3 shows the systems evaluation process applied in Chapter 5. The purpose of the simulation is to evaluate the validity of LFG scheme which enables to share risk and return between an airline and an airport. Based on the operation of the Haneda-Noto flight, I developed a Systems Dynamics model decomposing it into four sub-systems: a flight and passenger sus-system, a load factor guarantee sub-system, a load factor adjustment sub-system and a demand adjustment sub-system (Fig. 5.4). The model is tested comparing with the historical data of the flights from 2003 to 2004. Statistical examination is conducted using Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE). After simulating on the baseline setting, I conduct two scenario studies, on negotiation scenario and on subsidy scenario, for evaluating the business systems behaviours. Strategic insights are derived through comparison and discussions to find a way to manage unsustainable regional air transport services to remote regions.

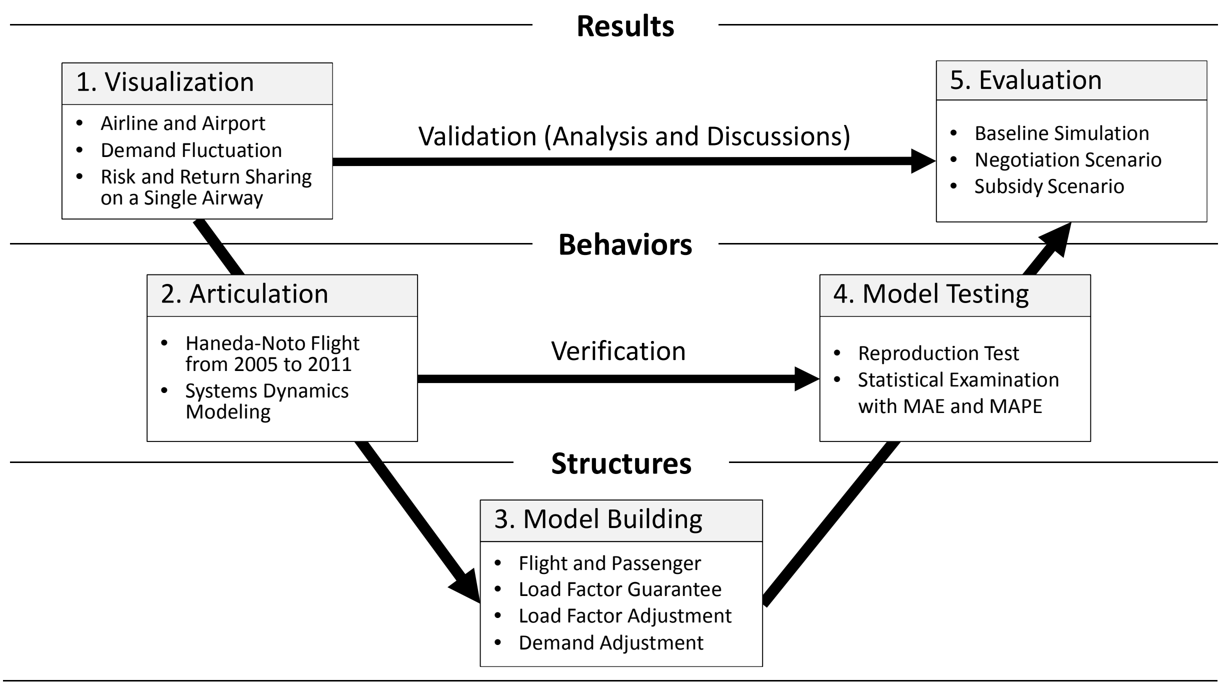


Fig. 5.3 Systems evaluation process (Chapter 5)

5.3.2. System Dynamics Modelling

I used Systems Dynamics for modelling since it enables to represent physical and information flows based on information feedback controls that are continuously converted into decisions and actions (Suryani, Chou, and Chen, 2010). I developed the SD model to calibrate a general LFG management framework adopted by an airline and an airport. The model consists of four different subsystems: 1) a flight and passenger subsystem, 2) a demand adjustment subsystem, 3) a load factor adjustment subsystem, and 4) a load factor guarantee subsystem. Fig. 5.4 shows a subsystem diagram describing the overall architecture of the model.

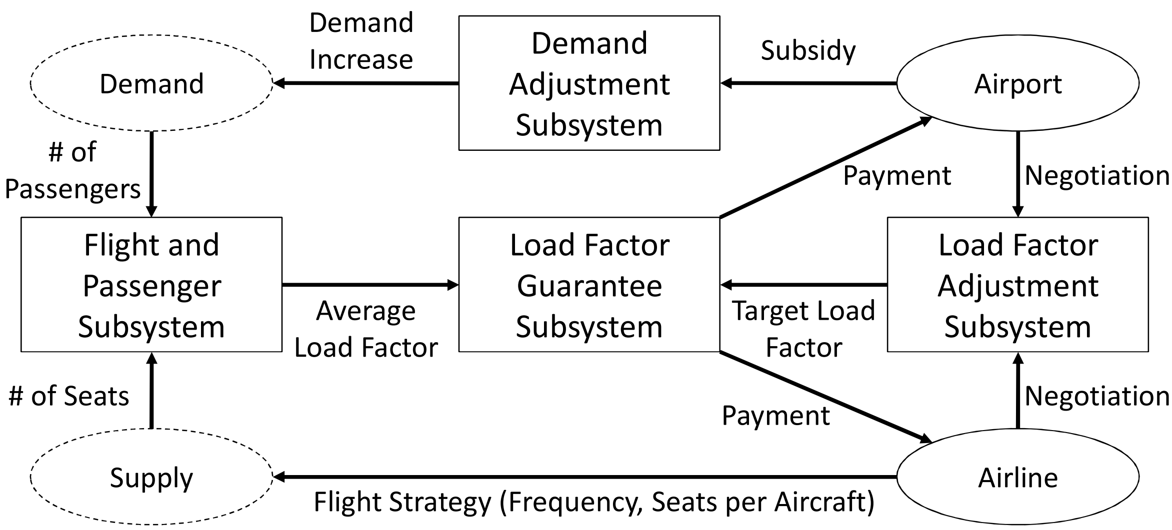


Fig. 5.4 Overview of the model (Subsystem Diagram)

An airline provides flights depending on its flight strategy, taking into account frequency and fleet. The strategy defines supply in terms of the number of seats, while the number of passengers is generated by market demand based on historical data. The flight and passenger subsystem generates the average load factor as an input into the LFG subsystem. The airline and airport negotiate within the load factor adjustment subsystem and generate a target load factor as an input into the LFG subsystem. Payment is calculated based on the discrepancy between the average and target load factors. When a certain discrepancy exists between the two, an airport with financial support from the local government that owns it attempts to stimulate passenger demand by providing subsidies. Hence, airline–airport coexistence is expected to be maintained through the LFG scheme.

5.4. Model Building

5.4.1. Modelling of Flight and passenger subsystem

Fig. 5.5 shows the stock and flow diagram (SFD) for a flight and passenger subsystem. There are two stocks in the model: 1) Accumulated Number of Seats Provided, which generates a supply to the system, and 2) Accumulated Number of Passengers, which generates a demand for the system. The Average Load Factor is computed using these two stock variables.

An inflow to the stock, Monthly Number of Seats Provided, is computed as the multiple of four variables: Number of Days per Month, Number of Flights per Day, Number of Seats per Aircraft, and Operation Reliability. Each variable is set based on the historical data, as summarized in Table 2. The monthly supply is accumulated into the stock for 12 months and is repeatedly discarded at the end of a year by Timing of Calculation using the pulse train function of Vensim.

The other inflow to the stock, Monthly Number of Passengers, is computed by summing the Monthly Passenger Demand and Subsidized Passenger Demand. Monthly Passenger Demand is set based on the historical data using the lookup function, as in Table A1 in Appendix A. We assume that the demand in the months of May and June 2012 would be the same as in May and June of the previous year because actual data were not yet available.

Subsidized Passenger Demand is computed using the Demand Adjustment Subsystem, which is explained later. Monthly demand is accumulated into the stock for 12 months and repeatedly discarded at the end of a year. This discard might not be realistic for practical air transport business operations; however, we designed this model to simulate the game between the airline and the airport. At the end of each year, they compute the average load factor for the year to determine payments to the other, and the result does not influence next year’s passenger demand.

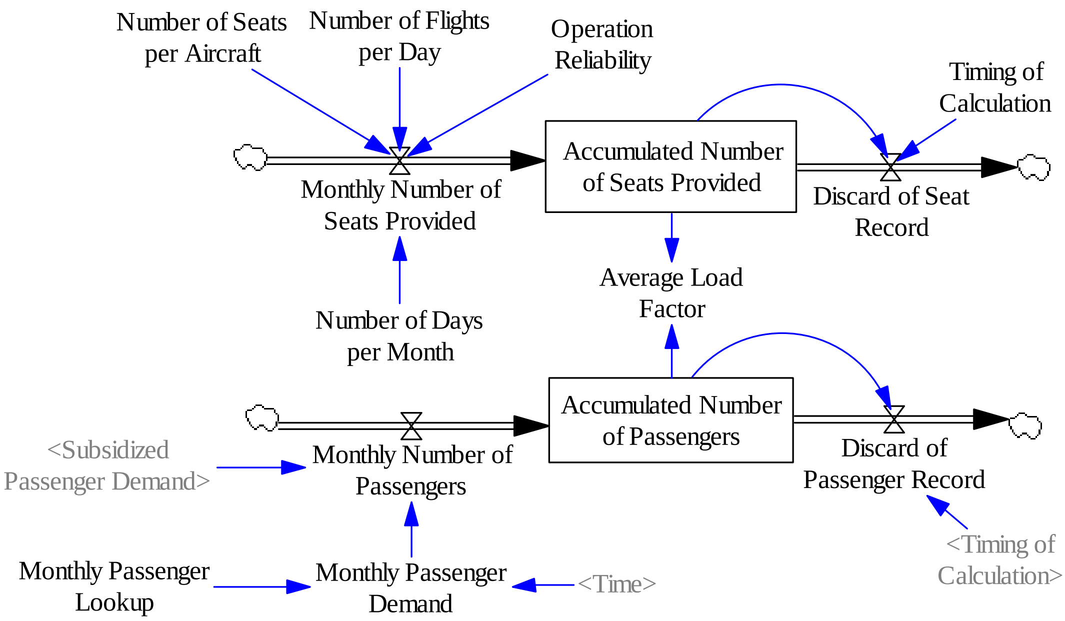


Fig. 5.5 Flight and passenger subsystem

5.4.2. Modelling of Load factor guarantee subsystem

Fig. 5.6 shows the SFD for the LFG subsystem. Two main stocks are used in the model: 1) Financial Stock of Airline, calculated in Eq. 5.1, and 2) Financial Stock of Airport, calculated in Eq. 5.2. The term 'financial stock' means the latest cash position of an airline and airport, enabling the evaluation of their financial states through a monitoring of these stock variables.

An airport pays the Guarantee Fee calculated in Eq. 5.3 when the Average Load Factor is lower than the Target Load Factor. An airline pays the Cooperation Fee calculated in Eq. 5.4 when the Average Load Factor is larger than the Target Load Factor. Each payment is calculated at the end of a year according to the Timing of Calculation. The unit payment is set based on the historical data, as shown in Table 5.2.

$$\textbf{Financial Stock of Airline} = \sum \text{Guarantee Fee} - \text{Cooperation Fee}$$

Eq. (5.1)

$$\textbf{Financial Stock of Airport} = \sum \text{Cooperation Fee} - \text{Guarantee Fee}$$

Eq. (5.2)

$$\textbf{Guarantee Fee} = \text{If then else (Target Load Factor} > \textit{Average Load Factor}, \textit{Accum}\text{ulated Number of Seats Provided} \times \text{Discrepancy of Load Factor} \times \text{Unit Payment} \times \text{Timing of Calculation}, 0)$$

Eq. (5.3)

$$\textbf{Cooperation Fee} = \text{If then else (Average Load Factor} > \textit{Target Load Factor}, \textit{Accum}\text{ulated Number of Seats Provided} \times \text{Discrepancy of Load Factor} \times \text{Unit Payment} \times \text{Timing of Calculation}, 0)$$

Eq. (5.4)

5.4.3. Modelling of Load factor adjustment subsystem

Fig. 5.7 shows the SFD for the Load Factor Adjustment Subsystem. The model contains one stock variable, Target Load Factor. Each stakeholder negotiates to adjust the Target Load Factor according to the Discrepancy of Load Factor, which depends on the Timing of Calculation. The Target Load Factor is increased when the Average Load Factor is larger than the Target Load Factor of the previous year. In contrast, the Target Load Factor is decreased when the Average Load Factor is lower than the Target Load Factor. The Load Factor Adjustment Rate defines the adjusted discrepancy. Since Actual Adjustment should be integrals, the remainder is subtracted from the Load Factor Adjustment.

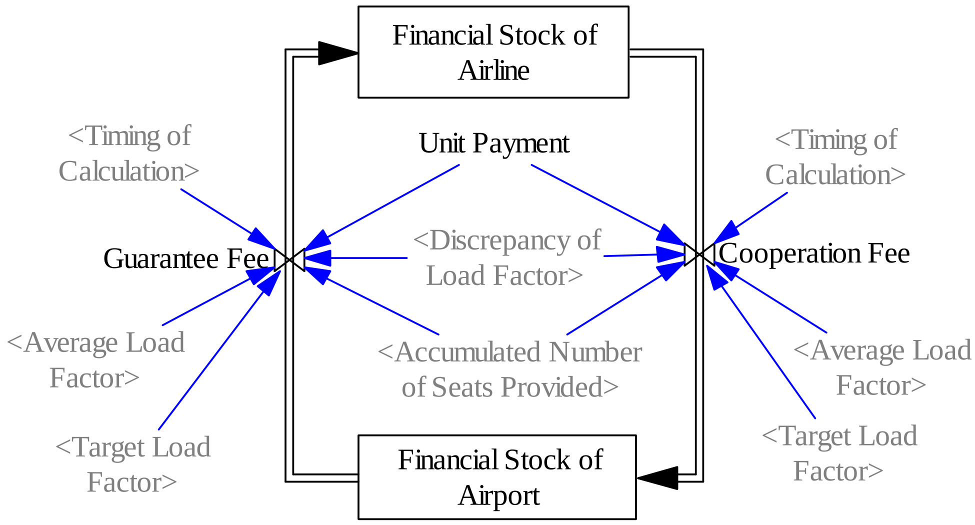


Fig. 5.6 LFG subsystem

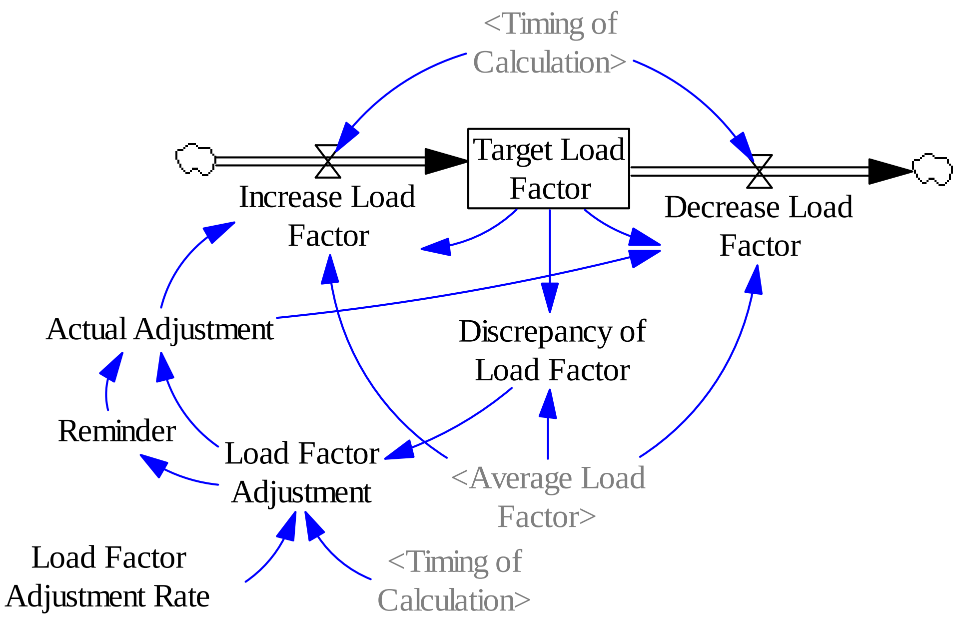


Fig. 5.7 Load factor adjustment subsystem

5.4.4. Modelling of Demand adjustment subsystem

Fig. 5.8 shows the SFD for the Demand Adjustment Subsystem. The demand is adjusted according to the discrepancy between the Target Load Factor and the Average Load Factor of the previous year and the Demand Adjustment Rate (DAR). We assume that the demand adjustment is conducted by controlling the ticket price with subsidies. Ticket Price Elasticity of Demand is computed in Eq. 5 (Murakami et al., 2008, 59–64),

$$\text{Price Elasticity of Demand } (e_t) = -\frac{(q_{t+1} - q_t)/q_t}{(p_{t+1} - p_t)/p_t}$$

Eq. (5.5)

where q is demand and p is price. In addition, we assume that Price Elasticity of Demand is fixed throughout the simulation and is set at −0.74 for the baseline simulation (Yamauchi 2000, 195–225). Converting Eq. 5.5, the Required Decrease of Ticket Price is computed as in Eq. 5.6, which defines Subsidy per Ticket. The total amount of the subsidy is computed using the multiple of Subsidized Passenger Demand and Subsidy per Ticket. The subsidy payment is accumulated in the stock of Accumulated Amount of Subsidy. We evaluate how much an airport and a local government should spend by adjusting the Average Load Factor.

$$\text{Required Decrease of Ticket Price} = -\frac{(q_{t+1} - q_t) \times p_t}{q_t \times e_t}$$

Eq. (5.6)

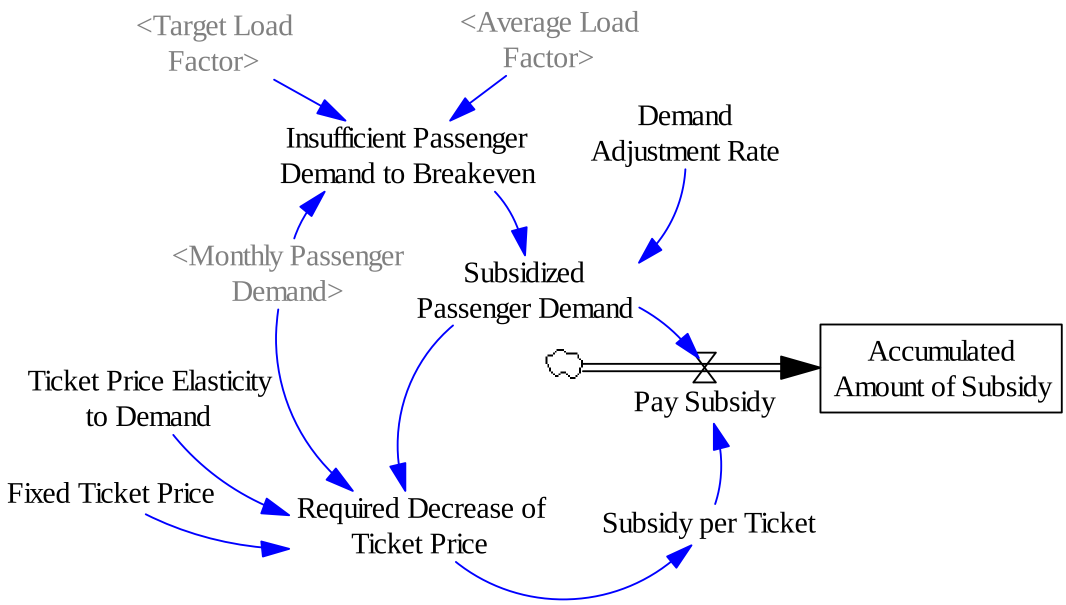


Fig. 5.8 Demand adjustment subsystem

Table 5.3 Assumptions for parameters (Source: NAPC, ANA, Ishikawa Prefecture)

Variable name	**Value**	**Unit**
Number of Flights per Day	4	Flights
Number of Seats per Aircraft	166 (Airbus A320)	Seats
Number of Days per Month	30	Days
Operation Reliability	0.99	
Fixed Ticket Price	275 ($1USD = ¥80JPY)	USD
Unit Payment	75 ($1USD = ¥80JPY)	USD
Price Elasticity of Demand	−0.74 (Yamauchi 2000, 195-225)	

5.5. Model Testing

I tested the model using the historical data of Haneda–Noto flight in 2003 and 2004 (NAPC). These two years are appropriate for validation for two reasons. First, since the average load factors exceeded the guaranteed load factors in each year, ANA transferred some of its revenues to the prefectural government as Cooperation Fee. It means that I can examine validity of the model behaviour according to the actual reactions of the both parties. Second, for this particular LFG, both parties agreed on special ranges around the guaranteed load factor, making both parties exempt from payments since 2005. However, the model excluded this in order to present a more generalised simulation of a LFG. It means that the historical data after 2005 was distorted by the influence of the special agreement and thus not appropriate for validation. Therefore, I used the year of 2003 and 2004 for validation of the model.

I compared the two data series in terms of Average Load Factor, payment of Cooperation Fee and Guarantee Fee. I used three measures for examining the data fit: 1) Absolute Error in Eq. (5.7) for each item for each year, Mean Absolute Error (MAE) in Eq. (5.8) and Mean Absolute Percentage Error (MAPE) in Eq. (5.9) for each item for two years. Absolute Error is used for understanding the discrepancy between two data. Both MAE and MAPE provide a measure of the average error between the simulated and actual series (Sterman, p. 874, 2000) but MAPE is dimensionless.

$$\text{Absolute Error} = |X_m - X_d| \qquad \text{Eq. (5.7)}$$

$$\text{MAE} = \frac{1}{n}\sum |X_m - X_d| \qquad \text{Eq. (5.8)}$$

$$\text{MAPE} = \frac{1}{n}\sum \frac{|X_m - X_d|}{X_d} \qquad \text{Eq. (5.9)}$$

Table 5.4 showed the comparison results. In 2003, the agreed load factor was 70% and the result of the average load factor was 79.9% (NAPC). I think the high load factor was partly because of the extensive interest of the local residents in opening of a new airway to remote region and partly of the small size of the fleet to the demand. As a result, ANA was required to pay 1,216,620 USD (97, 329, 6000 JPY) of Cooperation Fee to Ishikawa Prefecture (ANA). It leaded the both parties to revise the detail conditions. In 2004, the both parties renegotiated the load factor agreement and changed it from 70% to 63% (NAPC). In addition, ANA upsized the feet from 126 seats of Boing 737 to 170 seats of Airbus A320.

Regarding the average load factor, the historical data in 2003 was 79.5 and the simulation result was 79.8, which is only 0.3 of deviation to the historical data. In 2004, the historical data was 64.6 and the simulation result was 64.3, which is also only 0.3 of deviation to the historical data. The MAE is 0.15 and the MAPE is only 0.4%. There is good fit between the two data series and I think the behaviour was well reproduced by the model.

Regarding the Guarantee Fee, the simulation results are identical to the historical data both in 2003 and 2004. The model succeeded in reproducing exact behaviours occurred in the past.

Regarding the Cooperation Fee, there were cash transfers from ANA to Ishikawa prefecture both in 2003 and 2004. The historical data in 2003 was 1,216,620 USD (97, 329, 6000 JPY) and the simulation result was 1,365,950 USD and the deviation was 149,330 USD. In 2004, the historical data was 199,750 USD (15,800,000 JPY) and the simulation result was 242,221 USD and the deviation was 42,471 USD. The MAE is 95,900 USD and the MAPE is 16.7%. The simulation results shows some deviation in Cooperation Fee payment to the historical data but I think it mainly due to the impact of currency exchange rate ($1USD = ¥80JPY in this analysis). I decided to use the developed model for scenario simulation in the following.

Table 5.4 Model validation (Source: Hihara (2012), NAPC, ANA and simulation)

Item	Year	His. Data X_d	Sim.Result X_m	Abs. Error Eq. (5.7)	MAE Eq. (5.8)	MAPE Eq. (5.9)
Average Load Factor (%)	2003	79.5	79.8	0.3	0.30	0.4%
	2004	64.6	64.3	0.3		
Guarantee Fee (USD)	2003	0	0	0	0	0%
	2004	0	0	0		
Cooperation Fee (USD)	2003	1,216,620	1,365,950	149,330	95,900	16.7%
	2004	199,750	242,221	42,471		

5.6. Results and Discussions

I examine three different scenarios: 1) baseline, 2) negotiation, 3) subsidy. The baseline scenario does not include any measure of the impact on the system. The negotiation scenario includes adjustment to the rate of the guaranteed load factor. The subsidy scenario includes a demand adjustment using ticket subsidies. For each scenario, we run the simulation for 84 months (seven years). The length of the simulation is based on the current practice of the LFG between Noto Airport and ANA subsequent to the fixing of the fleet size using the Airbus A320 with 166 seats in 2005 (NAPC 2012).

5.6.1.Baseline scenario

I set a baseline scenario assuming no load factor adjustment or demand adjustment. Fig. 5.9 shows the financial stock and Fig. 5.10 the accumulated payment of the airline and the airport. The movements of each financial stock are horizontally symmetrical because neither party took an adjustment action. In the beginning, the airline continuously pays for the airport as there is adequate air passenger demand. However, the trend begins to change around year five, driven by increased demand. Then, the airport has to pay for the airline to fulfil the load factor discrepancy. Both parties sometimes win and sometimes lose; thus, the airline–airport relationship is not a path-dependent system. Although the amount of the payments will probably be balanced in the long run, the airline must temporarily bear the negative financial situation. This situation might force the airline to withdraw from the entered airway route. We consider some measures for sustaining the coexistence of airline and airport.

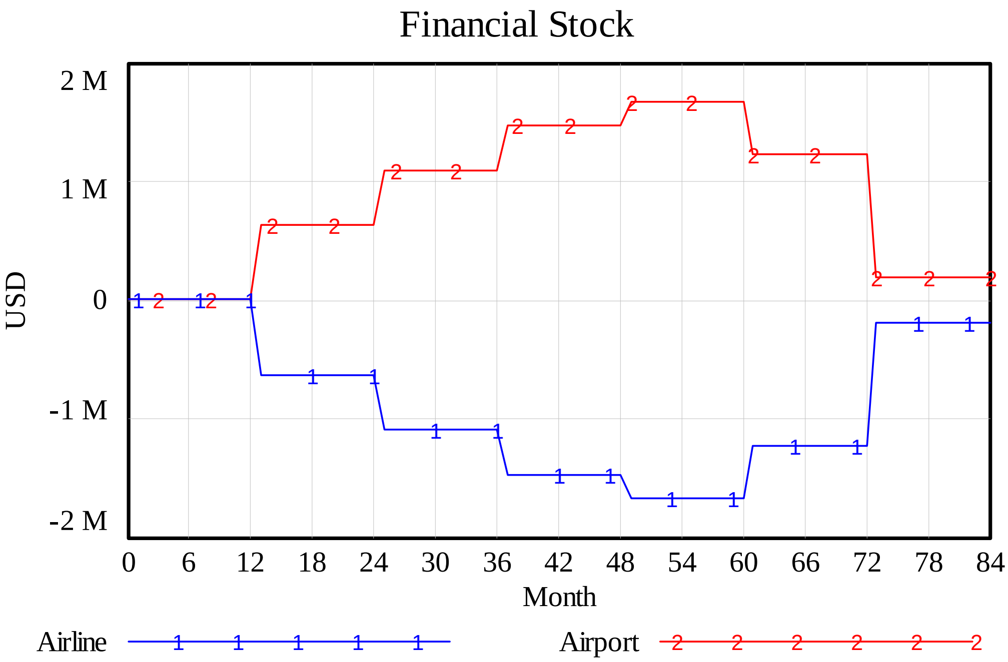


Fig. 5.9 Financial stock (Baseline Scenario)

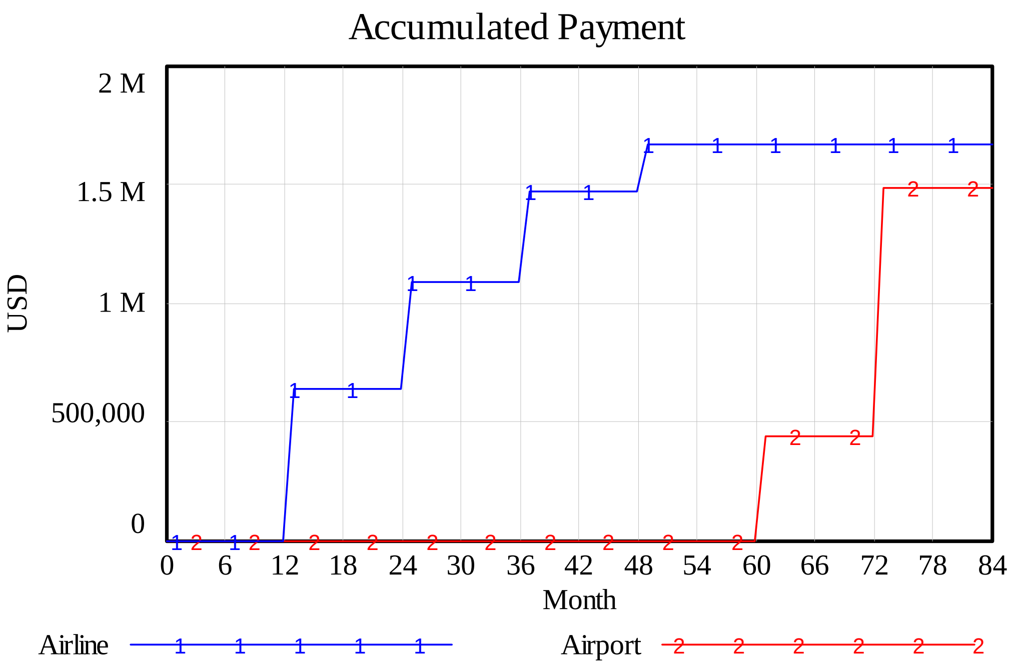


Fig. 5.10 Accumulated payment (Baseline Scenario)

5.6.2.Negotiation scenario

Next, I examine the negotiation scenario highlighting the Load Factor Adjustment Subsystem (Fig. 5.7). We assume that each stakeholder negotiates to adjust the Target Load Factor according to the discrepancy of the load factor in the previous year. We then implement a parametric study on the Load Factor Adjustment Rate (LFAR), setting it as 0%, 20%, 40%, 60%, 80%, and 100%, without any adjustment on the demand side.

Fig. 5.11 shows the results of the Financial Stock of Airline. No distinction exists among the scenarios during the first two years, implying that the load factor adjustment is inactive given the appropriate design of LFAR according to the expected demand. At 20% of LFAR, although the result is the same as the baseline, we find an incremental improvement when LFAR increases.

In contrast, Fig. 5.12 shows the results of the Financial Stock of Airport. Compared with the baseline, although the result is no different at 20% of the LFAR, it decreases according to the LFAR, contrary to the airline findings. When the result is positive for the airline, the result is always negative for the airport. The movements were totally symmetrical, meaning that introducing the Load Factor Adjustment works satisfactorily to improve the benefit of the airline; at the same time, however, it also lessens the benefit of the airport. Thus, an appropriate trade-off must be designed between the airline and the airport for the sake of long-term coexistence. We examine a subsidy scenario to find a way to improve the airline's financial state without aggravating the airport's financial state.

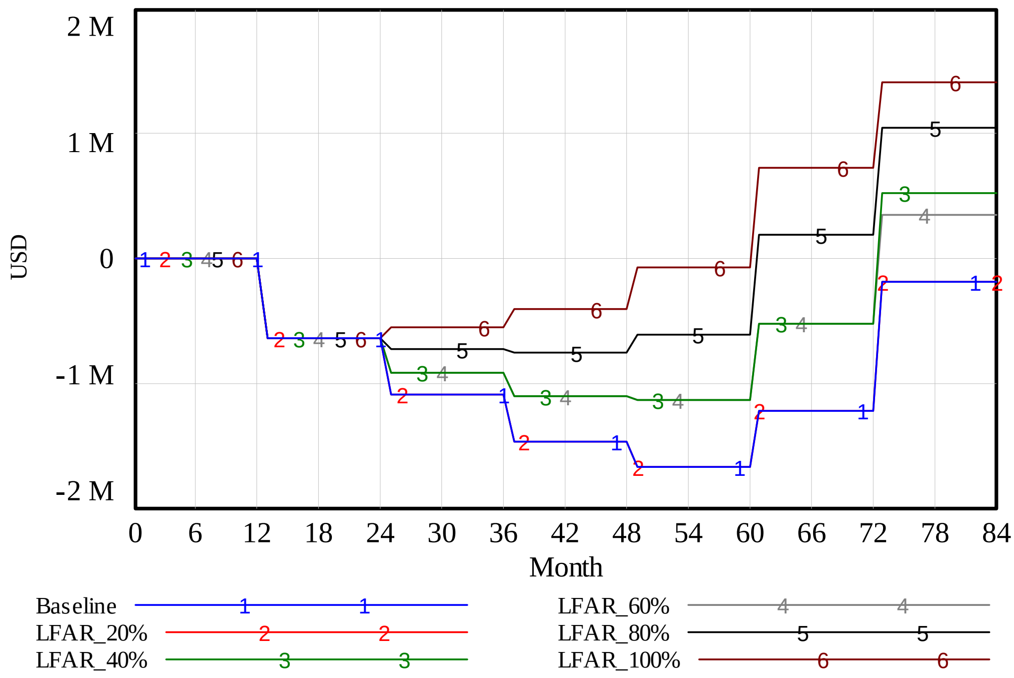


Fig. 5.11 Financial Stock of Airline (Negotiation Scenario)

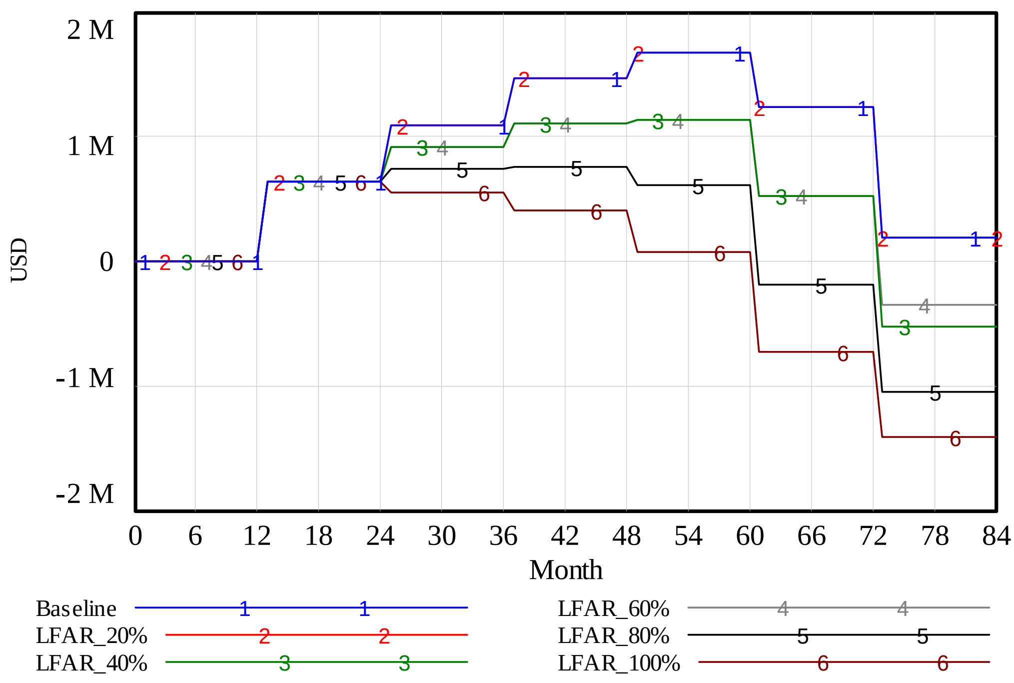


Fig. 5.12 Financial Stock of Airport (Negotiation Scenario)

5.6.3.Subsidy scenario

Management by negotiation using the Load Factor Adjustment benefits the airline but not the airport; therefore, we believe that an airline–airport coexistence is not sustainable over the long term. Therefore, we next examine the subsidy scenario, highlighting the Demand Adjustment Subsystem (Fig. 5.8). The simulation aims to balance the benefits to the airline with those to the airport. I assume that an airport increases the number of air passengers when a certain discrepancy in the load factor exists. In this simulation, an airport increases demand using a ticket subsidy, assuming financial support from the local government that owns the airport based on the discrepancy in the load factor of the previous month.

The model was modified to reflect the impact of the subsidy payment and demand increase for both parties, as shown in Fig. 5.13. Payment for the subsidy was subtracted from the Financial Stock of Airport because the subsidy requires a certain amount of expenditures from an airport. In contrast, additional revenues were expected for the airline because the number of air passengers increased due to the subsidy effect. Additional Passenger Revenue is computed by multiplying Subsidized Passenger Demand and Fixed Ticket Price. I implemented a parametric study on the DAR, setting it as 0%, 20%, 40%, 60%, 80%, and 100%, without any adjustment to the load factor.

Fig. 5.14 shows the results of the Financial Stock of Airline. No distinction exists among the scenarios during the first four years, indicating that demand adjustment is inactive because air passenger demand was adequate. After year five, the demand adjustment is finally activated because of inadequate demand. Although the baseline scenario shows negative results throughout the simulation period, the other scenarios achieve positive results with the demand adjustment in the end (Fig. 5.14), illustrating that the airline's financial state improves with an increased DAR.

In contrast, the Financial Stock of Airport shows unique movements (Fig. 5.15). No distinction exists among the scenarios during the first four years. However, the demand adjustment becomes active after year five, according to the DAR setting. In principle, we expect that the higher the DAR, the higher the expenditures from the airport, meaning that the airport's financial state is also worsened by an increased DAR. Interestingly, however, the airport's financial state remained positive with an increased DAR, which we believe occurred because the

Subsidized Passenger Demand's feedback effect contributed to an increase in the average load factor and thus ultimately a reduced Guarantee Fee airport payment. In all scenarios other than the baseline scenario, the financial stocks were positive in the end, meaning that both the airline and the airport are likely to be satisfied with operations and thus that airline–airport coexistence can be sustained. Introducing a monthly demand adjustment system, as in the simulation, can balance the benefits to airlines with those to airports.

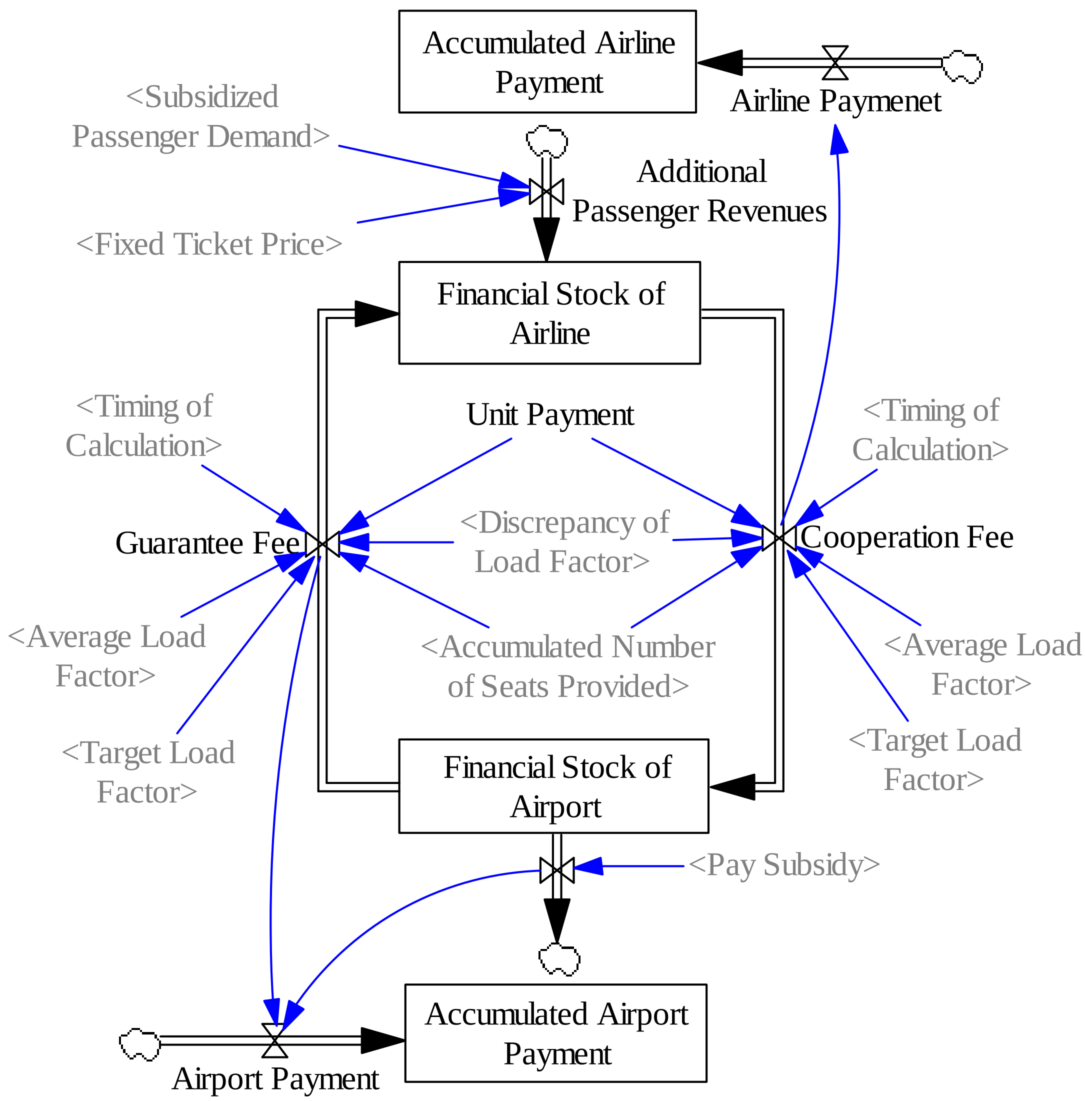


Fig. 5.13 LFG Subsystem (Modified)

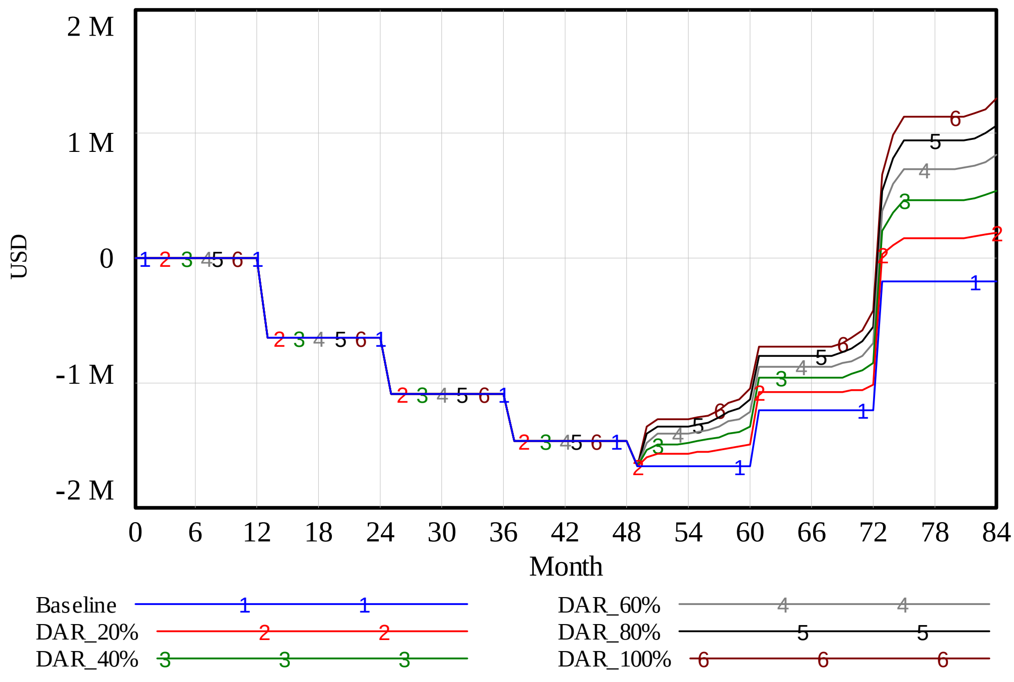


Fig. 5.14 Financial Stock of Airline (Subsidy Scenario)

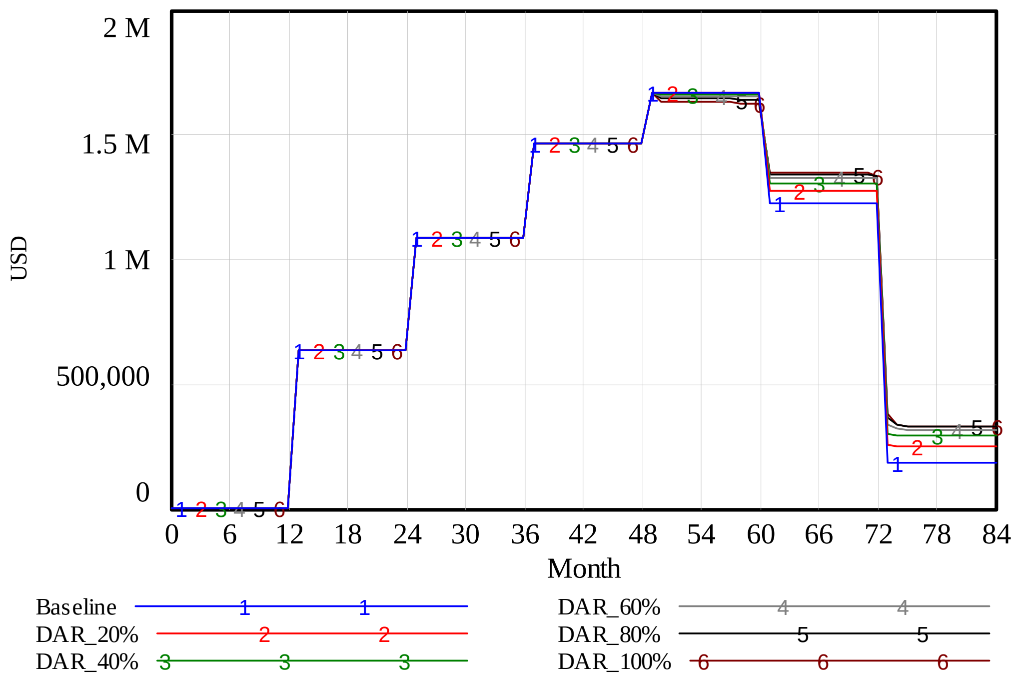


Fig. 5.15 Financial Stock of Airport (Subsidy Scenario)

5.7. Chapter Conclusions

This chapter aims to examine the possibility of risk and return sharing between an airline and airport on a single airway. I focused on discussing the validity of a load factor guarantee scheme for sustaining airline–airport coexistence. The results show that merely negotiating on a target load factor is insufficient for balancing the benefits to an airline with those to an airport; mutualism for both parties is not sustainable. Integrating the LFG and the monthly demand adjustment is the key to successful airline–airport coexistence. Although integration of a subsidy with an LFG means a temporary financial loss for an airport and local government, our research indicates that such a measure is the most effective way of maintaining long-term airline–airport coexistence.

Under the competitive environment after the air deregulation, airports and airlines need to work together to improve their relationship and to develop close links and partnerships (Graham, 2006). The proposed SD model can help an airport and airline understand the interdependency of their business systems and the need to cooperate to enhance their business sustainability. The load factor guarantee can be used to reduce the business risk of entering a new airway for which air traffic demand and profitability are uncertain. Considering the depopulation in remote areas such as peninsulas and remote islands, however, a load factor guarantee cannot sustain long-term mutualism due to the estimated air traffic reduction. Other management strategies might be able to enhance the mutualism within a regional air transport system. Thus, the following chapter compares several management strategies for sustaining unprofitable regional air transportation by considering its impact on regional air transport communities.

(Intentionally Blank)

PART 3

Durability of Business Systems

(Intentionally Blank)

Chapter 6. Air Transportation Ecosystem

In Part 3, Chapter 6 and Chapter 7, I discuss durability of business systems. In Chapter 6, I examine broader scope of regional air transport stakeholders, such as local government and local communities (Fig. 6.1). I regard it as air transport ecosystem, a concept originally from ecology. It also reflects the problem of how to sustain a flight to Tokyo (see 1.4.1) but considers more on community perspective facing decay of business systems. Using system dynamics, I simulate the impact of several management strategies on the entire air transportation ecosystem and discuss how to manage it sustainably.

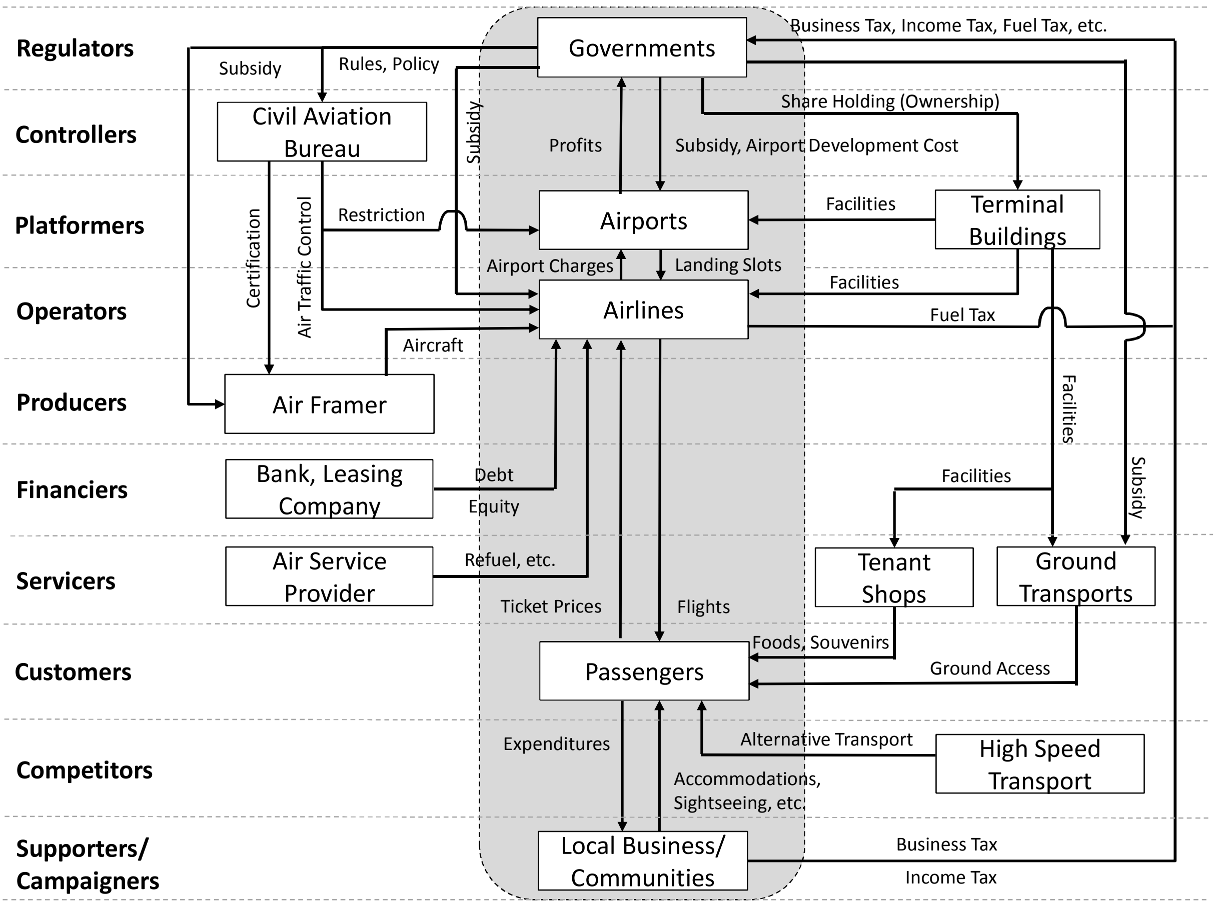


Fig. 6.1 Scope of Chapter 6 (Air transportation ecosystem)

6.1. Chapter Introduction

Although airport management tries to maximize economic benefits, particularly revenues from retail services (Graham, 2003), most regional airports lack substantial traffic, making retail revenue generation difficult (Lei and Papatheodorou, 2010). Slot capacity is generally ample at regional airports, but the geographical distribution of air traffic is unbalanced. Humphreys and Francis (2002b), analysing regional airports in the UK, find that 'enough airport capacity exists but not where airlines want it'. Feldhoff (2002), examining regional Japanese airports, finds that airports cannot be defined solely according to natural and regional economic features and characterises air transport as having a 'unipolar structure' (Feldhoff, 2003). Thus, location is critical for regional airports.

When airports are constructed near local cities where adequate air traffic cannot be expected, special strategies are needed to sustain the commercial viability of the air transport service. Governments subsidize aircraft purchases, reduce airport charges, compensate airlines for revenue losses, and even guarantee flight load factors. Governments also encourage local residents to fly by offering them subsidised discounted tickets.

Unfortunately, these strategies are generally designed in isolation by government departments addressing a single issue rather than as parts of a broader policy. Strategies lack the 'system' perspective, 'system' being defined as a 'combination of interacting elements organized to achieve one or more stated purposes' (INCOSE Systems Engineering Handbook, 2010). Air transport is composed of a combination of airports, airlines, aircraft, passengers, governments, and communities. Systematic analysis is required for an understanding of the interactions of the multiple stakeholders comprising the system's complex behaviour.

Using an analogy with biological ecosystems, I analyse regional air transport as an ecosystem comprising regional air transport stakeholders and propose strategies for sustaining them. The degree of the effectiveness and the national implications of regional airports will depend on the use of performance indicators encompassing all stakeholders (Humphreys and Francis, 2002a). Thus, the ecosystem approach is essential. The research objectives in this chapter are as follows:

(1) To visualize Japan’s regional air transport as ecosystems that include airports, airlines, aircraft, passengers, local governments, and local communities.
(2) To establish a simulation model for this ecosystem and evaluate several management strategies, including load factor guarantees, profit-loss compensation, reductions in airport charges, and subsidized airfare.
(3) To propose optimal management strategies for enhancing the commercial sustainability of regional air transport as an ecosystem.

The remainder of this chapter is organized as follows. The section 6.2 explains the data used for systems evaluation. The section 6.3 explains the methodology used in the study. The section 6.4 explains model building process and the section 6.5 describes model testing results. The section 6.6 presents an analysis and discussions based on the simulation results. The section 6.7 provides the conclusions and identifies the study’s limitations.

6.2. Data for systems evaluation

I use the case of Haneda-Noto flight as in chapter 5. Table 6.1 shows the flight and passenger records from 2003 to 2009 used in the simulation (Noto Airport Promotion Council (NAPC), 2010). As explained in the previous chapter, this LFG requires ANA to operate twice-daily flights between Haneda and Noto. Whenever actual load factors are below the guaranteed threshold, the prefecture government compensates ANA for the difference. When the load factor exceeds the guaranteed factor, ANA transfers some revenues to the prefectural government. Both parties have agreed on a maximum payment.

In 2005, however, both parties further agreed to ranges around the guaranteed load factor within which both parties are exempt from payment. In 2005, for example, the guaranteed load factor was 64%. However, the government had to pay ANA only when the actual load factor was below 63%, while ANA had to pay the government only when the load factor exceeded 65% (NAPC, 2010). The SD model in chapter 5 excluded this additional agreement to the special ranges around the guaranteed load factor, but, in this chapter, I calibrate a new SD model to consider the entire ecosystem.

Table 6.1 Historical Data on the Haneda-Noto flight from 2003 to 2009 (NPAC)

	2003	2004	2005	2006	2007	2008	2009
# of Seats in A/C	126	170	166	166	166	166	166
# of Passengers	151,015	155,623	160,052	156,945	158,558	150,365	148,768
Seats Provided	189,987	241,017	240,575	241,195	242,517	241,437	239,294
Average LF	79.5%	64.6%	66.5%	65.1%	65.4%	62.3%	62.2%
Target LF	70%	63%	64%	62%	62%	62%	62%
Airline pays	>70%	>63%	>65%	>66%	>66%	>66%	>66%
Government pays	<70%	<63%	<63%	<58%	<58%	<58%	<58%

6.3. Methodology

6.3.1. Systems evaluation process

Fig. 6.2 shows the systems evaluation process applied in Chapter 6. I first capture the structure of the regional air transport ecosystem using a causal loop diagram consisting of variables connected by arrows denoting the causal influences among variables. Important feedback loops are also identified in the diagram to enable a dynamic hypothesis about how the problem is caused within a system. Second, I formulate a simulation model using a stock and flow diagram (SFD), a tool for diagramming stock and flow and feedback structures in a system. Third, the model is tested comparing with the historical data of the flights from 2003 to 2009. Statistical examination is conducted using Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE). Forth, I simulate several management strategies and examine the balance among financial state of airline, airport and government. Finally, strategic insights are derived to find a way to manage unsustainable regional air transport services to remote regions.

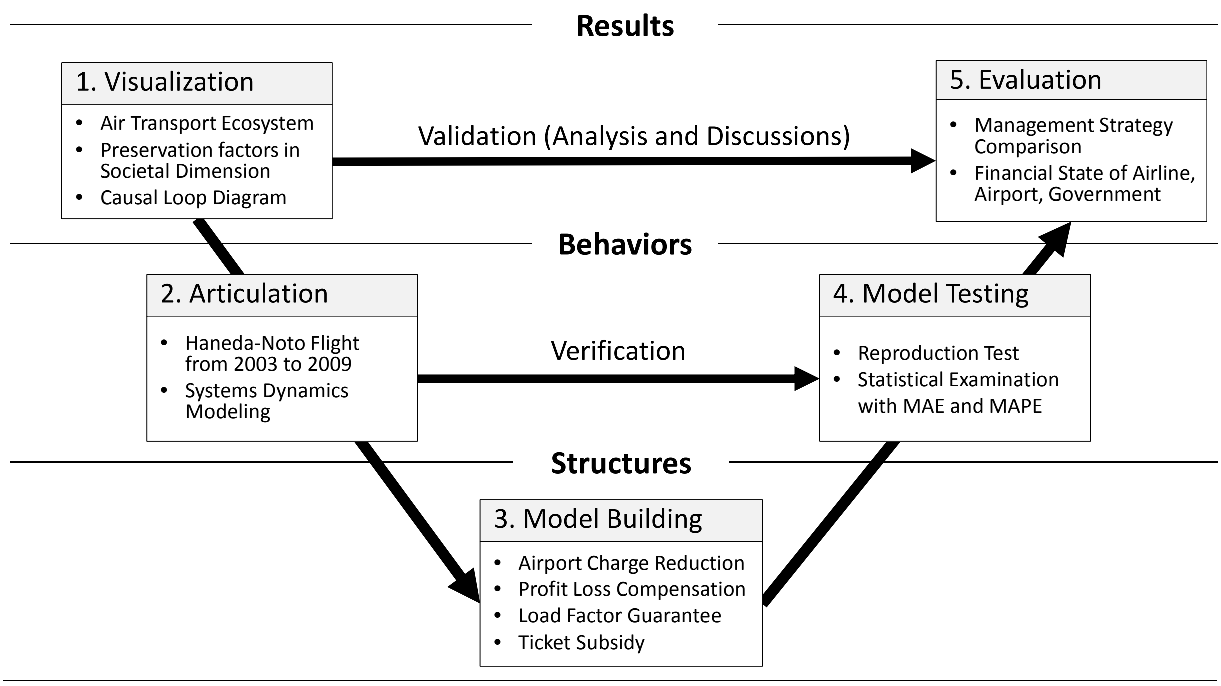


Fig. 6.2 System evaluation process (Chapter 6)

6.3.2. Dynamic hypothesis with Causal loop diagram (CLD)

I created the CLD for two purposes: 1) to visually portray the ecosystem of regional air transport and 2) to generate a working theory that accounts for problematic behaviour (Fig. 6.3). Airlines, airports, passengers, local governments and local communities are identified as major stakeholders in the ecosystem. I examine six management strategies commonly used to sustain unprofitable regional air transport: 1) fuel tax reductions, 2) airport charge reductions, 3) subsidies for aircraft purchases, 4) profit loss compensation, 5) load factor guarantees, and 6) subsidies for airline tickets.

A systems analysis based on the CLD provides several insights into problematic behaviour. In this case, initiating one of these strategies as a solution would achieve only partial optimization of the ecosystem and impair its long-run sustainability. For example, a fuel tax reduction (FTR) and airport charge reduction (ACR) affect the ecosystem both positively and negatively. They reduce airlines' operating costs and improve their financial conditions, but they also reduce revenues to governments and airports. These strategies thus sustain airlines at the expense of other stakeholders.

Subsidies for aircraft purchase (SAP) and profit loss compensation (PLC) sustain airlines by sacrificing the financial condition of the governments that own and manage regional airports. Airports and passengers are ignored in these two strategies, and thus the ecosystem is not likely to be commercially sustainable in the long run.

Load factor guarantees (LFG), examined in chapter 4, encourage airlines to operate commercially unstable flights at regional airports since government shares the business risk. An LFG generally affects the ecosystem positively by sharing the risk and the return between airlines and governments, but they do not benefit passengers. Thus, the entire ecosystem is not likely to be commercially sustainable in the long run.

Finally, subsidies for air tickets (SAT) benefit the ecosystem in several ways. By increasing the number of passengers, subsidies boost airline revenues. More passengers mean more spending at the airport and in the community, expanding the local economy. Economic growth attracts more people seeking to live and work in the region, generating more air passengers. A greater volume of passengers lifts the load factors and prompts the same effects as load factor guarantees. Ticket subsidies require expenditures from government, but tax revenues are likely to rise as revenues increase inside the ecosystem. Thus, I hypothesise that ticket subsidies are the most efficient and effective strategy for sustaining the entire ecosystem. I examine the hypothesis using a computer-aided simulation based on the SFD.

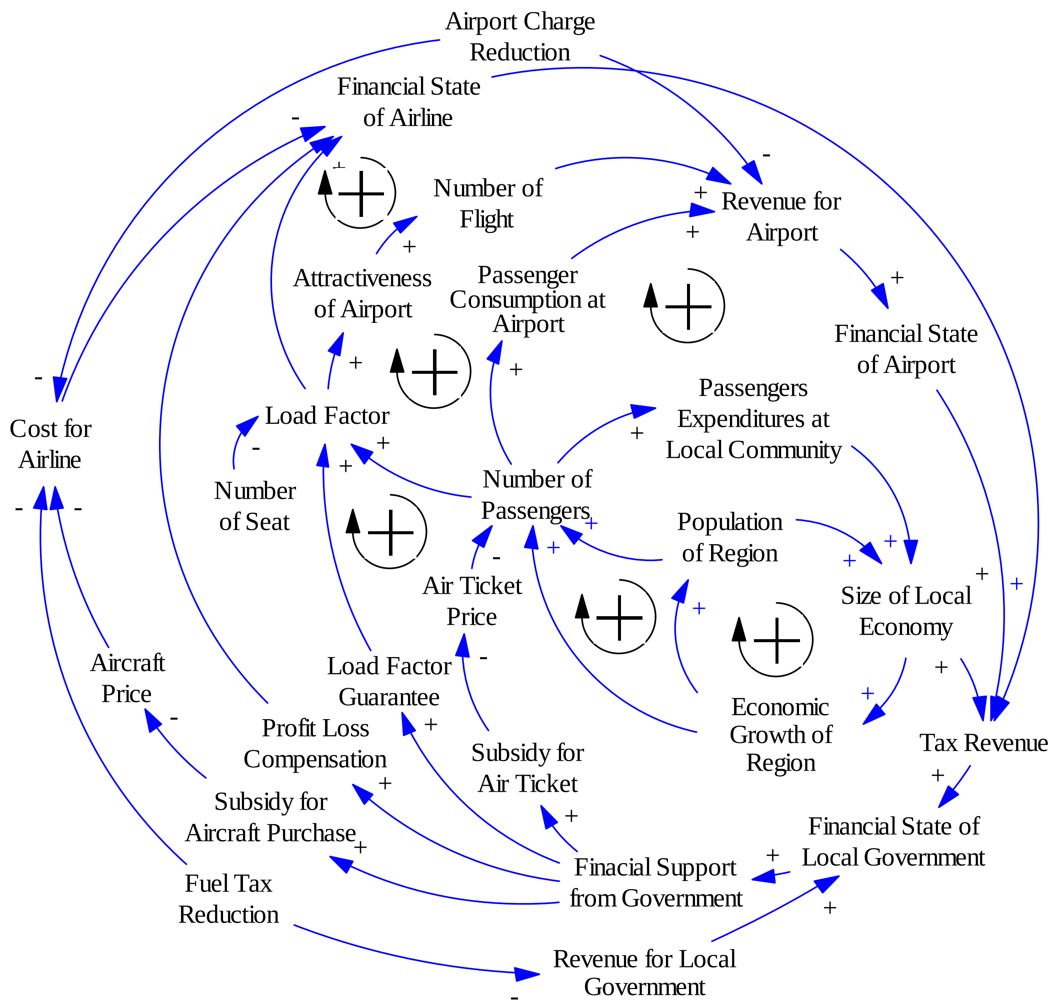


Fig. 6.3 Causal Loop Diagram for the Regional Airport Ecosystem

6.4. Model Building

Fig. 6.4 presents an overview of the SFD. Three stocks are designed and represented by rectangles in the SFD: Financial State of Airline, Financial State of Airport, and Financial State of Local Government. I focus on the financial effects on each stakeholder, drawing on commercially based indicators referenced in the scholarship (Humphreys and Francis, 2002a). I examine these stocks because they describe the 'states of the system upon which decisions and actions are based, are the source of inertia and memory in systems that create delays, and generate disequilibrium dynamics by decoupling the rate of flow' (Sterman, pp. 229, 2000). The variables designed for the model to reproduce the ecosystem include the annual number of air passengers, daily frequency, passenger yield, unit operating cost per available tonne-km, and guaranteed load factor. The assumptions are shown in Table 6.2. Most are derived from the historical data on Haneda-Noto flights and Noto Airport.

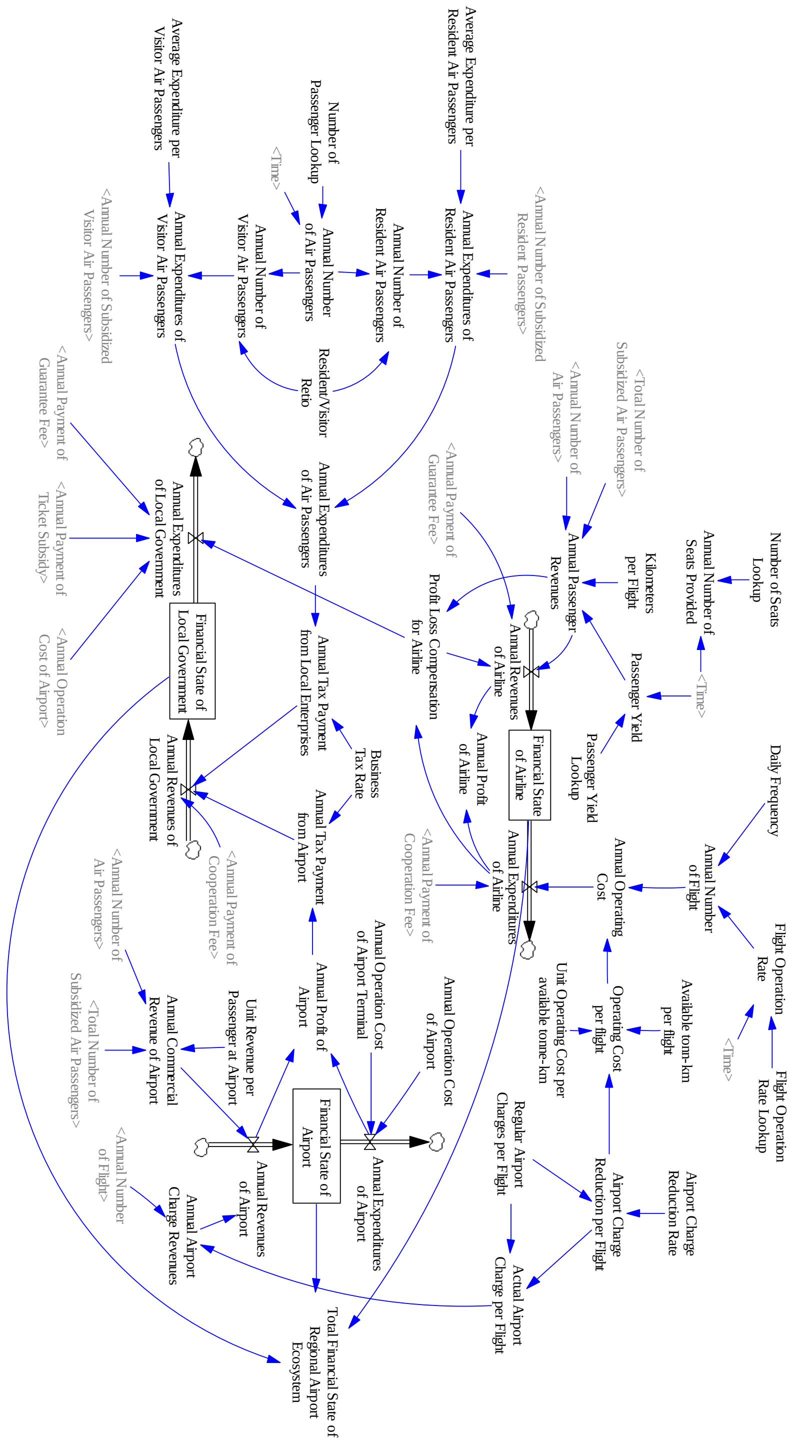


Fig. 6.4 Overview of Stock and Flow Diagram (SFD)

Table 6.2 Assumptions of parameters used in the simulation

Name of Variables	Values	Unit	Sources
Frequency per Day	4	flight	NAPC
Kilometre per Flight	331.2	km	ANA
Available tonne-km per Flight	11,546	t-km	MLIT
Unit Operating Cost per Flight	56.52	JPY	ICAO (Doganis)
Business Tax Rate	7.2	%	Ishikawa Pref.
Resident/Visitor Ratio	20/80	%	MLIT
Average Ticket Price (2003–2009)	13,724~16,359	JPY	ANA
Passenger Yield (2003–2009)	16.0~18.6	JPY	ANA
Ticket Subsidy per Passenger	2,000	JPY	NAPC
Price Elasticity of Domestic Air Travel	-0.74	-	Yamauchi, 2000
Average Expenditures per Resident PAX	13,829	JPY	Ishikawa Pref.
Average Expenditures per Visitor PAX	40,013	JPY	Ishikawa Pref.
Unit Revenue per Passenger at Airport	2,694	JPY	Ishikawa Pref.
Airport Charge Local per Flight	77,700	JPY	MLIT
Airport Charge Reduction Rate	2/3	-	RIETI
Annual Operation Cost of Airport	241,016,000	JPY	Ishikawa Pref.
Annual Sales of Airport Terminal	400,836,000	JPY	Ishikawa Pref.
Annual Operation Cost of Airport Terminal	338,095,000	JPY	Ishikawa Pref.
JPY-USD Exchange Rate	1$=82.52	JPY	Bank of Japan

6.4.1. Modelling of Airline sub-system

The Financial State of Airline is calculated by summing the difference between the Annual Expenditures of Airline and the Annual Revenues of Airline, as in Eq. (6.1).

$$\textbf{Financial State of Airline} = \sum(\text{Annual Revenues of Airline} - \text{Annual Expenditures of Airline})$$

Eq. (6.1)

The Annual Revenues of Airline is calculated by summing Annual Passenger Revenues, Annual Payment of Guarantee Fee, and Profit Loss Compensation, as in Eq. (6.2).

$$\begin{aligned}\textbf{Annual Revenue of Airline} &= \text{Annual Passenger Revenue} + \text{Annual Payment of Guarantee Fee} \\ &+ \text{Profit Loss Compensation}\end{aligned}$$

Eq. (6.2)

where Annual Passenger Revenue is calculated in Eq. (6.3). Passenger Yield and Kilometre per Flight are based on ANA's financial reports and flight information.

$$\begin{aligned}\textbf{Annual Passenger Revenue} &= \text{Passenger Yield} \times \text{Kilometer per Flight} \\ &\times (\text{Annual Number of Air Passenger} \\ &+ \text{Total Number of Subsidized Air Passenger})\end{aligned}$$

Eq. (6.3)

The Annual Expenditures of Airline is calculated by summing Annual Operating Cost and Annual Payment of Cooperation Fee, as in Eq. (6.4)

$$\textbf{Annual Expenditures of Airline} \\ = \text{Anual Operating Cost} + \text{Annual Payment of Cooperation Fee}$$

Eq. (6.4)

where Annual Operating Costs is calculated in Eq. (6.5)

$$\textbf{Annual Operating Costs} = \text{Annual Number of Flight} \times \text{Operating Cost per Fight}$$

Eq. (6.5)

where Annual Number of Flight is calculated as Daily Frequency multiplied by Flight Operation Rate based on the Noto Airport Promotion Council (NPAC), and Operating Cost per Flight is calculated as in Eq. (6.6)

$$\begin{aligned}&\textbf{Operating Cost per Flight} \\ &\quad = \text{Unit Operating Cost per available tonne km} \times \text{Available toone km per Flight} \\ &\quad - \text{ Airport Charge Reduction per Flight}\end{aligned}$$

Eq. (6.6)

The Profit Loss Compensation is provided only when there were profit losses for airlines in the previous year and is calculated in Eq. (6.7). The payment is added to Financial State of Airline in the following year in the simulation.

$$\textbf{Profit Loss Compensation} \\ = |\text{Annual Expenditures of Airline} - \text{Annual Passenger Revenue}|$$

Eq. (6.7)

Although onboard commercial sales are revenue sources for LCCs, we exclude them from the simulation since they are likely to be insignificant for regional flight and would have little impact compared to the other revenues.

6.4.2. Modelling of Passenger sub-system

The Annual Number of Air Passengers is based on the historical NAPC record. We assume that 20% of them are resident passengers and 80% of them are visitor passengers. This Resident/Visitor Ratio is based on the report of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT, 2010). We assume that resident passengers spend 13,829 JPY ($167.6 USD) on average during a trip and that visitor passengers spend 40,013 JPY ($484.8 USD). These numbers are based on the sightseeing statistics of tourism (Sightseeing Statistics of Ishikawa Prefecture, 2009). The Annual Expenditures of Resident Air Passengers is calculated in Eq. (6.8) and the Annual Expenditures of Visitor Air Passengers in Eq. (6.9).

$$\begin{aligned}\textbf{Annual Expenditures of Resident Air Passengers}\\ &= \text{Average Expenditure per Resident Air Passenger}\\ &\times (\text{Annual Number of Resident Air passenger}\\ &+ \text{Annual Number of Subsidized Resident Air Passengers})\end{aligned}$$

Eq. (6.8)

$$\begin{aligned}\textbf{Annual Expenditures of Visitor Air Passengers}\\ &= \text{Average Expenditure per Visitor Air Passenger}\\ &\times (\text{Annual Number of Visitor Air passenger}\\ &+ \text{Annual Number of Subsidized Visitor Air Passengers})\end{aligned}$$

Eq. (6.9)

6.4.3. Modelling of Local Government sub-system

The Financial State of Local Government is calculated by summing the difference between Annual Revenues of Local Government and Annual Expenditures of Local Government, as in Eq. (6.10),

$$\textbf{Financial State of Local Government} = \sum(\text{Annual Revenues of Local Government} - \text{Annual Expenditures of Local Government})$$

Eq. (6.10)

where the Annual Revenues of Local Government is the sum of the Annual Tax Payment from Local Enterprized and the Annual Tax Payment from Airport and calculated in Eq. (6.11). The Business Tax Rate is 7.2%, as is usual in Japan.

$$\textbf{Annual Revenue of Local Government} = \text{Business Tax Rate} \times (\text{Annual Tax Payment from Loca Enterprises} + \text{Anuual Tax Payment from Airport}$$

Eq. (6.11)

The Annual Expenditures of Local Government is calculated by summing the Annual Operation Cost of Airport, the Annual payment of Ticket Subsidy, the Annual payment of Guarantee Fee, and the Profit Loss Compensation, as in Eq. (6.12)

$$\textbf{Annual Expenditures of Local Government} = \text{Annual Operation Cost of Airport} + \text{Annual payment of Ticket Subsidy} + \text{Annual payment of Guarantee Fee} + \text{Profit Loss Compensation}$$

Eq. (6.12)

where the Annual Operation Cost of Airport is 241,016,000 JPY ($2,920,698 USD) according to the Ishikawa Prefecture and the Annual Payment of Ticket Subsidy is calculated in Eq. (6.13) assuming the effect of price elasticity, as explained in section 4.

$$\textbf{Annual Payment of Ticket Subsidy} = \text{Total Number of Subsidized Air Passengers} \times \text{Ticket Subsidy per Passenge}$$

Eq. (6.13)

6.4.4. Modelling of Airport sub-system

The Financial State of Airport is calculated by summing the difference between the Annual Revenues of Airport and the Annual Expenditures of Airport, as in Eq. (6.14),

$$\textbf{Financial State of Airport} = \sum(\text{Annual Revenues of Airport} - \text{Annual Expenditures of Airport})$$

Eq. (6.14)

where the Annual Revenues of Airport is the sum of the Annual Airport Charge Revenues and the Annual Non-aeronautical Revenues, as in Eq. (6.15),

$$\textbf{Annual Revenues of Airport} = \text{Annual Airport Charge Revenues} + \text{Annual Non} - \text{aeronautical Revenues}$$

Eq. (6.15)

where the Annual Airport Charge Revenues is calculated in Eq. (6.16),

$$\textbf{Annual Airport Charge Revenues} = \text{Annual Number of Flight} \times \text{Actual Airport Charge per Flight}$$

Eq. (6.16)

where the Actual Airport Charge per Flight is calculated in Eq. (6.17),

$$\textbf{Actual Airport Charge per Flight} = \text{Regular Airport Charge per Flight} - \text{Airport Charge Reduction}$$

Eq. (6.17)

Non-aeronautical revenues are calculated in Eq. (B18),

$$\textbf{Non} - \textbf{aeronautical Revenues} = \text{Unit Revenue per Passenger at Airport} \times (\text{Annual Number of Air Passenger} + \text{Total Number of Subsidized Air Passengers}$$

Eq. (6.18)

where the Unit Revenue per Passenger at Airport is assumed to be 2,694 JPY ($32.6 USD). We divide the annual sales of Noto Airport Terminal Building by the annual number of air passengers in 2009. According to the 2009 Profit and Loss statement of Noto Airport, the annual sales were 400,836,000 JPY ($4,857,440 USD), and the annual operating costs were 338,095,000 JPY ($4,097,128 USD).

6.4.5. Modelling of Load Factor Guarantee sub-system

Fig. 6.5 shows the structure of the LFG (Load Factor Guarantee). The annual average load factor is calculated by dividing the annual number of air passengers by the annual number of seats provided. The target load factor and the special range are set based on the historical records of the negotiation between the Ishikawa Prefecture and ANA. The payment line for the guarantee fee is the special range subtracted from the target load factor. The payment line for the cooperation fee is the sum of the special range and the target load factor. The guarantee fee is the payment made by local government when the annual average load factor is less than the payment rate for the guarantee fee and is calculated in Eq. (6.19). The cooperation fee is the payment made by airlines when the annual average load factor is more than the payment rate for the cooperation fee and is calculated in Eq. (6.20). In 2003 and 2004, ANA paid 97,000,000 JPY (1,175,472 USD)[2] to Ishikawa Prefecture as the cooperation fee for 9.5% of the load factor difference; I thus assume that an average payment per percentage of load factor difference would be 10,210,500 JPY (123,733 USD) in the simulation.

$$\begin{aligned}&\textbf{Annual Payment of Guarantee Fee}\\ &\qquad = |\text{Payment Line for Guarantee Fee} - \text{Annual Average Load Factor}|\\ &\qquad \times \text{Average Payment per \% of Load Factor Difference}\end{aligned}$$

Eq. (6.19)

$$\begin{aligned}&\textbf{Annual Payment of Cooperation Fee} =\\ &|\text{Annual Average Load Factor} - \text{Payment Line for Cooperation Fee}| \times\\ &\text{Average Payment per \% of Load Factor Difference}\end{aligned}$$

Eq. (6.20)

[2] 1$=82.52 JPY (as of February 2011 according to the Bank of Japan). I use the same exchange rate in the following JPY-USD calculation.

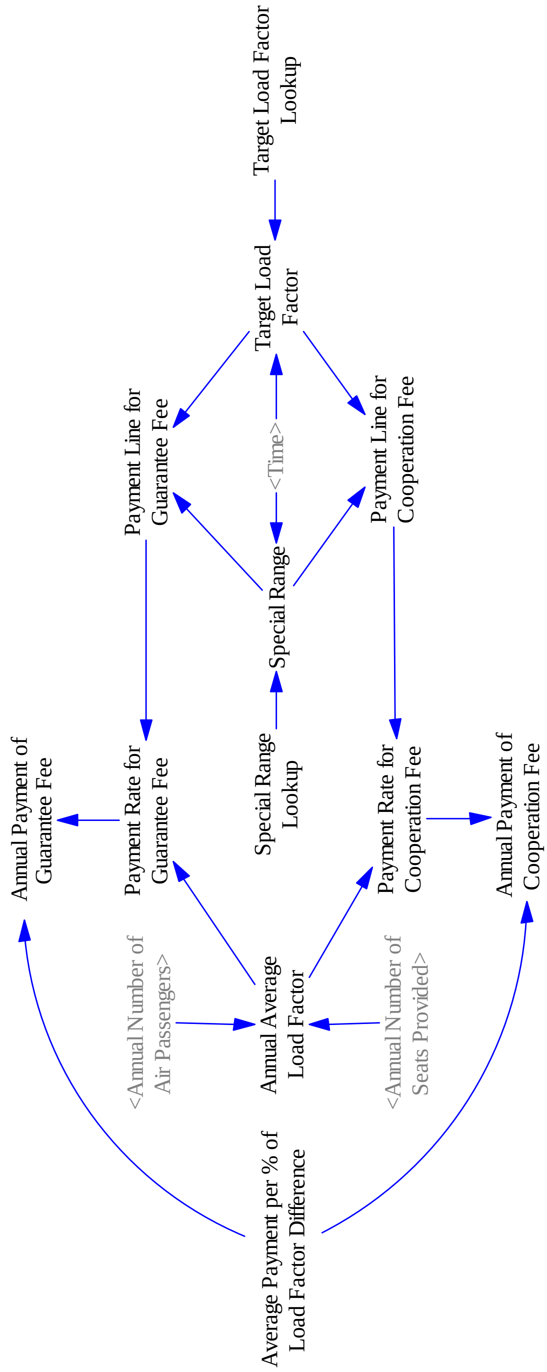


Fig. 6.5 Structure of Load Factor Guarantee (LFG)

6.4.6. Modelling of Ticket Subsidy sub-system

Fig. 6.6 shows the structure of the ticket subsidy. I consider the ticket price demand elasticity with the percentage change in demand as calculated with the percentage change in ticket price multiplied by the average price elasticity of domestic air travel. I set the price elasticity as -0.74, following research on Japan’s domestic air transport market (Yamauchi, 2000): ‘Price elasticity is always negative since price and demand must move in opposite directions’ (Doganis, pp. 198, 2010). The percentage change in ticket price is the ticket subsidy per passenger subtracted from the average ticket price. I assume a ticket subsidy per passenger per flight of 2,000 JPY (24.2 USD) based on the practice at Noto Airport Promotion Council. The average ticket prices are based on ANA’s financial reports from 2003 to 2009. The annual number of subsidized visitor air passengers is calculated as the annual number of visitor air passengers multiplied by the percentage change in demand. The annual number of subsidized resident air passengers is calculated as the annual number of resident air passengers multiplied by the percentage change in demand. The sum of the two numbers becomes the total number of subsidized air passengers. The annual payment of ticket subsidies is calculated as the ticket subsidy per passenger multiplied by the total number of subsidized air passengers.

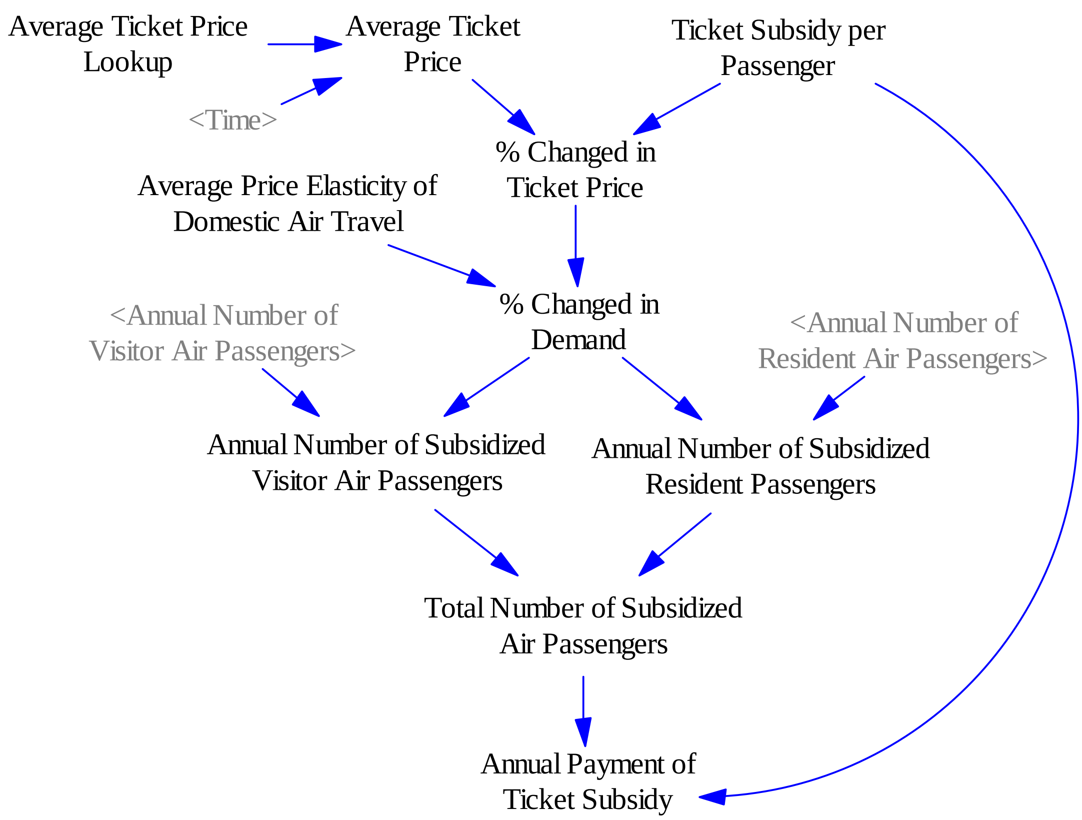


Fig. 6.6 Structure of Ticket Subsidy

6.5. Model Testing

I used historical data for the Haneda–Noto flight from 2003 to 2009 (NAPC) for validation of the simulation model. Validity of the model behaviour can be examined by comparing the simulation results (X_m) and the historical records (X_d) in terms of Average Load Factor, payment of Cooperation Fee and Guarantee Fee. Absolute Error is used for understanding the discrepancy between two data. Both MAE (Mean Absolute Error) and MAPE (Mean Absolute Percentage Error) provide a measure of the average error between the simulated and actual series (Sterman, p. 874, 2000) but MAPE is dimensionless.

$$\text{Absolute Error} = |X_m - X_d|$$

Eq. (6.21)

$$\text{MAE} = \frac{1}{n}\sum |X_m - X_d|$$

Eq. (6.22)

$$\text{MAPE} = \frac{1}{n}\sum \frac{|X_m - X_d|}{X_d}$$

Eq. (6.23)

Table 6.3 showed the results. Regarding the average load factor, the MAE is only 0.07 and the MAPE is only 0.1%. It implies that the deviation is not significant between the historical data and the simulation results. Regarding the Guarantee Fee, the simulation results are identical to the historical data throughout the data series. The model succeeded in reproducing exact behaviours occurred in the past. Regarding the Cooperation Fee, both in the historical data and the simulation results, cash transfer occurred in the first three years and no cash transfer occurred afterward. It implies that the model succeeded in reproducing the macroscopic behaviours of the reality. Also, the MAE is 710,728 JPY and the MAPE is only 3.2%. Since the MAPE is less than

10% in every item, I decided to use the developed model for scenario simulation in the following.

Table 6.3 Model validation (Source: Hihara (2012), NAPC, ANA, and simulation)

	Year	His. Data X_d	Sim. Result X_m	Abs. Error Eq. (6.21)	MAE Eq. (6.22)	MAPE Eq. (6.23)
Average Load Factor (%)	2003	79.5	79.4	0.1	0.07	0.1%
	2004	64.6	64.5	0.1		
	2005	66.5	66.5	0		
	2006	65.1	65.0	0.1		
	2007	65.4	65.3	0.1		
	2008	62.3	62.2	0.1		
	2009	62.2	62.2	0		
Guarantee Fee (JPY)	2003	0	0	0	0	0%
	2004	0	0	0		
	2005	0	0	0		
	2006	0	0	0		
	2007	0	0	0		
	2008	0	0	0		
	2009	0	0	0		
Cooperation Fee (JPY)	2003	97,329,600	96,786,600	543,000	710,728	3.2%
	2004	15,980,000	16,023,400	43,400		
	2005	20,000,000	15,611,300	4,388,700		
	2006	0	0	0		
	2007	0	0	0		
	2008	0	0	0		
	2009	0	0	0		

6.6. Results and discussion

I have evaluated the influence of several management strategies on the entire ecosystem. Subsidies for aircraft purchases have not been examined, since they apply only to remote island flight (Matsumoto, 2007). Fuel tax reduction was not examined either, since its influence is limited: the prefectural government, which owns the airport, receives only 0.03% of fuel tax revenues (Aviation Statistics, 2009). Other revenues from the fuel tax go to the national government or to community governments near the regional airport (Inoue, 2008).

6.6.1. Baseline scenario

For the baseline, I set a management strategy assuming that the government provides no special support to the ecosystem. Fig. 6.7 shows the financial state of the airline, airport, and local government under the baseline case. The financial state is the accumulation of cash inflow and outflow over time for each stakeholder and is calculated as the integral of each flow. The results show that the government incrementally improves its financial state, whereas the baseline case continuously aggravates the airline’s and airport’s financial states (see Fig. 6.7). The positive effects on the government come mainly from the increased tax revenues produced by air passengers’ expenditures at local enterprises. Since the air traffic demand is not large enough to make regional flights profitable, airlines are likely to be discouraged from operating them continuously. Appropriate management strategies are therefore necessary for maintaining the ecosystem. In the baseline case, the airport and airline are unlikely to be sustainable.

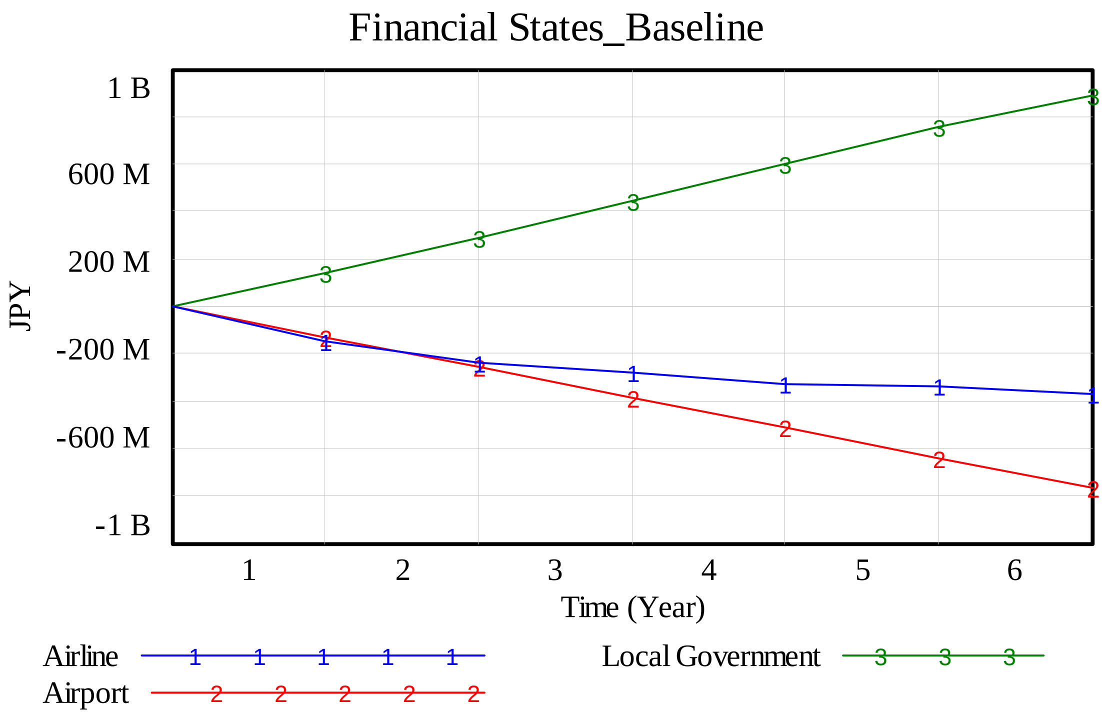


Fig. 6.7 Financial State (Baseline)

6.6.2. Management comparison

In addition to the baseline case, the simulation examines five management strategies: 1) Load Factor Guarantee (LFG), 2) Airport Charge Reduction (ACR), 3) Profit Loss Compensation (PLC), 4) Ticket Subsidies for Residents (TSR), and 5) Ticket Subsidies for Visitors (TSV). Fig. 6.8 through Fig. 6.15 shows the simulation results of the financial effects on each stakeholder of each management strategy: Baseline (marked 1), LFG (marked 2), ACR (marked 3), PLC (marked 4), TSR (marked 5) and TSV (marked 6). Ticket subsidies are divided into two categories, as subsidies on residents and those on visitors have different economic impacts. Visitor travellers pay not only for air tickets but also for accommodation, restaurants, and souvenirs. In fact, visitor travellers spend an average of 40,013 JPY (484.8 USD) and resident travellers an average of 13,829 JPY (167.6 USD) during a single trip (Sightseeing Statistics of Ishikawa Prefecture, 2009).

I first consider the financial state of the airline (Fig. 6.8). The results reveal that the ACR is the most desirable strategy for producing positive financial results; it decreases the airline’s operating cost directly and thus dramatically contributes to the profitability of the airline. The TSV is the second-most desirable strategy; it reduces the price of air tickets, which in turn results in additional demand creation according to the price elasticity of the air ticket. I use -0.74 as the average price elasticity for domestic air travel in Japan (Yamauchi, 2000). The PLC produced a negative financial state in the beginning; this gradually improved but never became positive. The PLC fills the gap between the airline’s costs and revenues but never provides additional cash above the break-even level. The financial state of the airlines continuously fluctuates under the TSR. Since the expenditures of resident travellers are far less than those of visitor travellers, the subsidy effect on additional demand creation is not large enough to make airlines profitable. There is no clear distinction between the LFG and the baseline since the LFG does not substantially increase air traffic demand nor decrease airlines’ operating costs but, rather, just mitigates the business risk. I thus conclude that the ACR is the best management strategy for improving the financial state of an airline, followed by TSV.

Second, I consider the financial state of the airport (see Fig. 6.9). Among the effects on airports, only the clear distinction involves the ACR, for which I assume that two-thirds of the airport charge is reduced at the regional airport (RIETI, 2007). The other strategies show almost the same results. The ACR is the best strategy for airlines (see Fig. 6.8) but the worst for airports (see Fig. 6.9). The ACR is a management strategy that improves the financial state of airlines at the cost of airports.

Finally, I consider the financial state of local government (see Fig. 6.10). Among the effects on local government, the only clear distinction involves the PLC, for which I assume that the difference between the airline’s revenues and costs in the previous year would be compensated by the local government in the following year. The other strategies show almost the same results, except that the TSV shows relatively desirable results. The PLC is a management strategy that improves the financial state of an airline (see Fig. 6.8) at the cost of local government (see Fig. 6.10).

To evaluate the trade-off among the management strategies, I have created a variable called ‘Total Financial State of Regional Airport Ecosystem’ (TFS), calculated as the sum of the three stocks in the SD model, the Financial State of Airline, the Financial State of Airport, and the Financial State of Local Government. The TFS indicates the overall effectiveness of each management strategy by considering the mutual benefits of airlines, airports, and the local government. The maximum TFS score indicates the most desirable strategy for the entire ecosystem. The simulation results (see Fig. 6.11) clearly show that the best strategy is the TSV.

The mechanism can be explained by considering the relationship between the annual expenditures of local government and the government's financial state. Although the TSV requires the second highest government expenditures (see Fig. 6.12), it returns the most benefits to the government (see Fig. 6.10). Furthermore, the TSV produces the second-most desirable results concerning the financial state of the airline (see Fig. 6.8). In other words, the TSV enables airline finances to improve without sacrificing government revenues. This benefit arises because of the increased number of visiting passengers, who generally spend more than resident passengers. This economic effect generates cash inside the ecosystem, from passengers to government, through tax revenues. The airport generates significant economic activity and can contribute to the development of the surrounding areas (Graham, 2003). On the other hand, the PLC requires the highest government expenditures (see Fig. 6.12) but does not return the highest benefit for the airline (see Fig. 6.8), the airport (see Fig. 6.9), or the local government (see Fig. 6.10).

Another important finding is that the airports' financial state never becomes positive in the simulation (see Fig. 6.9). Thus, all the management strategies examined are partially effective but none ensures the commercial viability of the entire ecosystem. I must therefore consider the generation of additional revenue sources for the airport within the ecosystem.

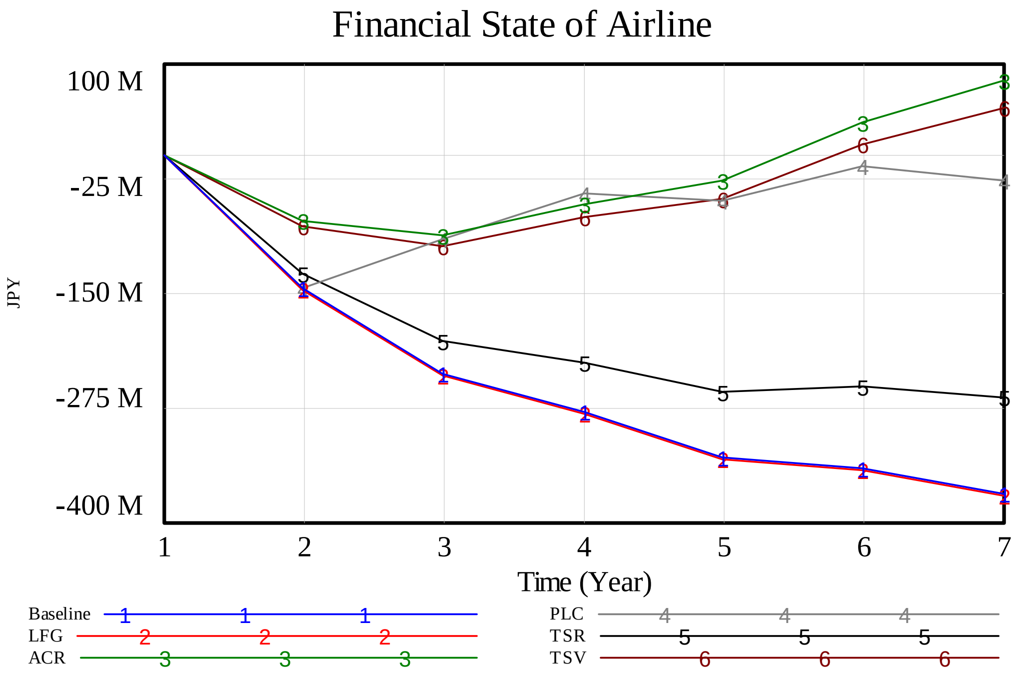


Fig. 6.8 Financial State of Airline

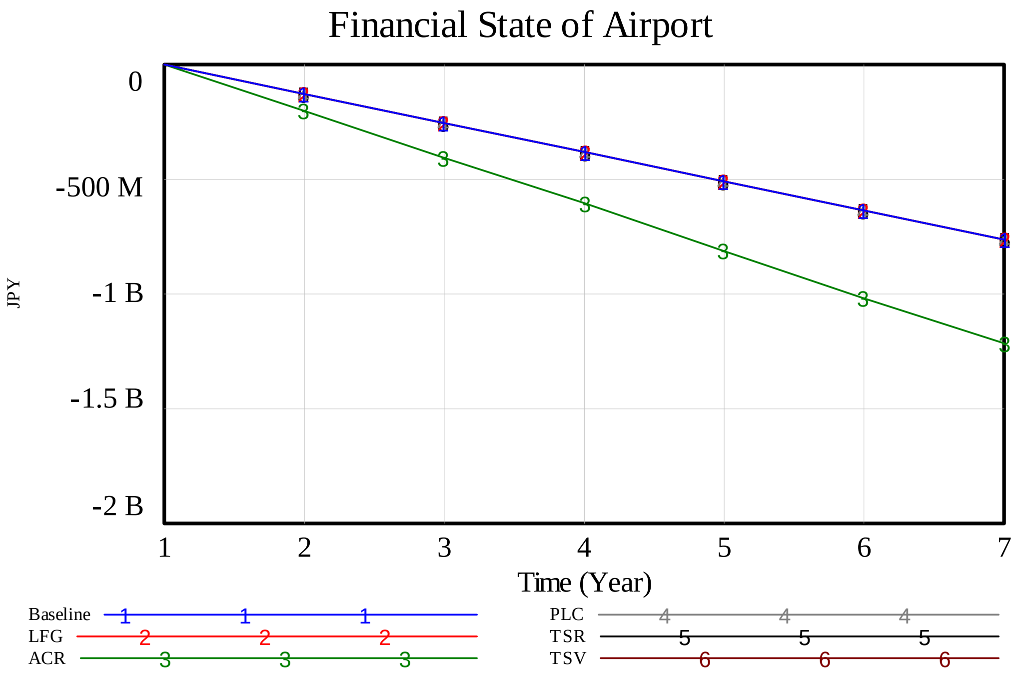


Fig. 6.9 Financial State of Airport

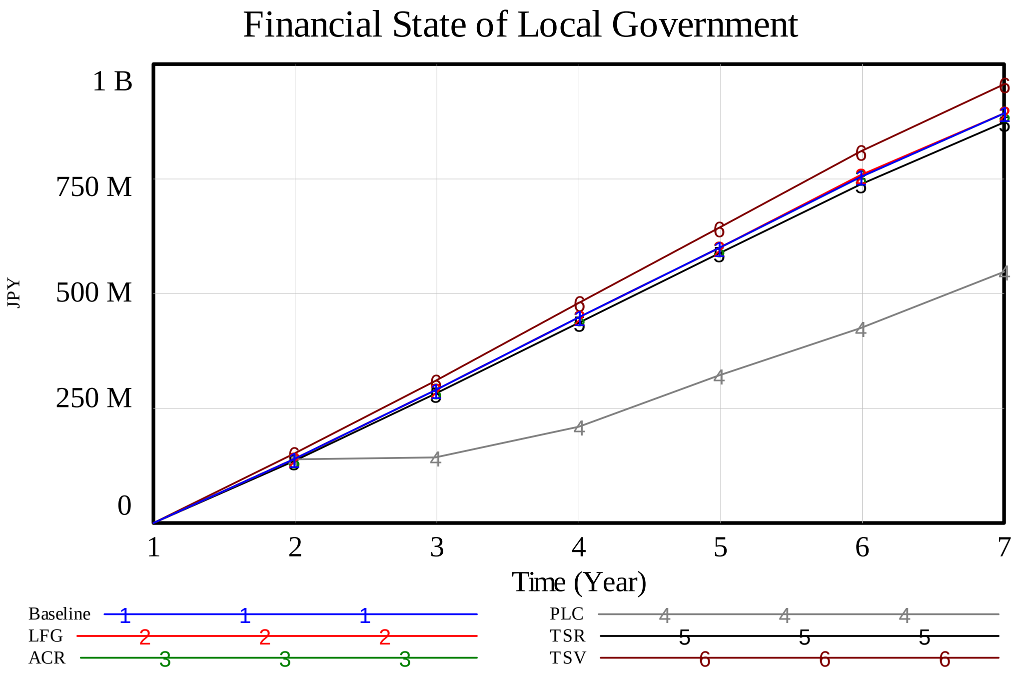


Fig. 6.10 Financial State of Local Government

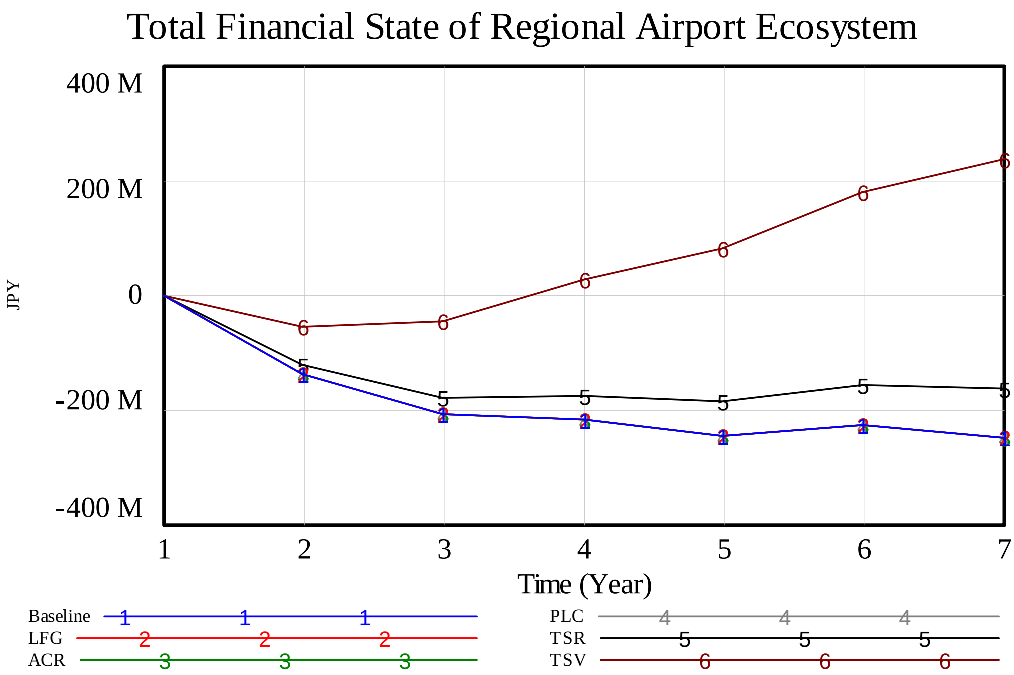


Fig. 6.11 Total Financial State of Regional Airport Ecosystem

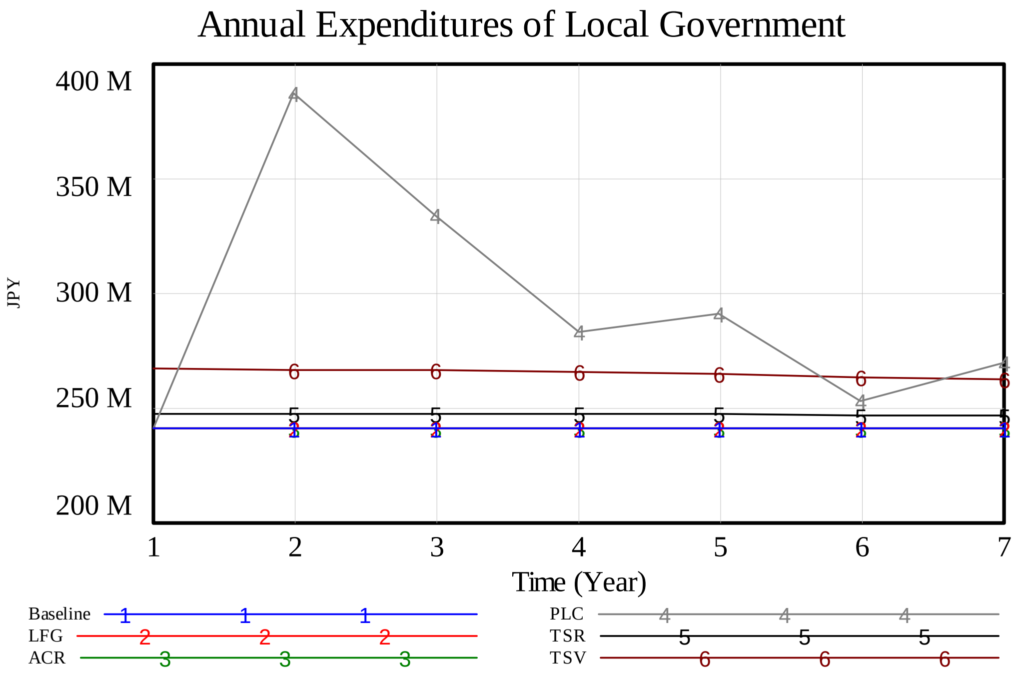


Fig. 6.12 Annual Expenditures of Local Government

6.6.3.Non-aeronautical revenue

I exclude non-aeronautical revenues from the simulation, assuming the traditional airport management practice in Japan. Japan's airport facilities are generally divided into two categories: 1) aeronautical facilities, such as runways and aircraft parking slots, and 2) non-aeronautical facilities, such as terminal buildings and car parks. In Japanese airports, unlike airports elsewhere, the two types of facilities are owned and managed by different entities (Nomura and Kiritooshi, 2010). The former are usually owned and managed by the public sector and the latter by private companies jointly established through public and private financing. This bilateral management means that airports cannot count on additional commercial revenues from passengers. Moreover, airport marketing is more innovative when administrated as an independent entity than when part of a regional or national system (Halpern, 2010). Thus, integrating the management of aeronautical and non-aeronautical facilities under one independent entity allows regional airports to earn revenues from both.

Fig. 6.13 shows the financial state of the airport when I consider non-aeronautical revenues. The average expenditure per passenger is based on the unit revenue per passenger at the airport. I divide the annual sales of the Noto Airport Terminal Building by the annual number of air passengers in 2009 and assume that each passenger would spend 2,694 JPY (32.6 USD) on average at the airport. According to the 2009 Profit and Loss statement of Noto Airport, annual sales were 400,836,000 JPY (4,857,440 USD) and the annual operating costs 338,095,000 JPY (4,097,128 USD). I include these figures for each year in the simulation. The airport's financial state improved through all the management strategies shown in Fig. 6.13 as compared with Fig. 6.8, but no management strategy made it possible to keep the airport's financial state positive throughout the simulation period (Fig. 6.13).

In Fig. 6.13, the TSV is likely to reach break-even if the average expenditure of passengers at the airport slightly increases. Therefore, another simulation considers the various amounts of average expenditure per passenger at the airport around the previous assumption (2,694 JPY): from 2,500 JPY (30.3 USD) to 3,000 JPY (36.4 USD). Fig. 6.14 presents the simulation results showing that the financial state of the airport can be positively maintained when the average expenditure per passenger at the airport is more than 2,800 JPY (33.9 USD).

Furthermore, including non-aeronautical revenues enables the total financial state of the regional airport ecosystem to show positive results through all management strategies (see Fig. 6.15). The TSV still shows the most desirable result, followed by the TSR. The other management strategies can eventually reach positive results as well, even though they will be in a negative financial state for the first couple of years. Although airport facility management is not integrated in Japan, this can enhance the commercial sustainability of the ecosystem. The combined strategy of TSV and the integral management of airports preserves and balances the benefits among airlines, airports, and governments. It is an effective design for the commercial sustainability of the entire ecosystem.

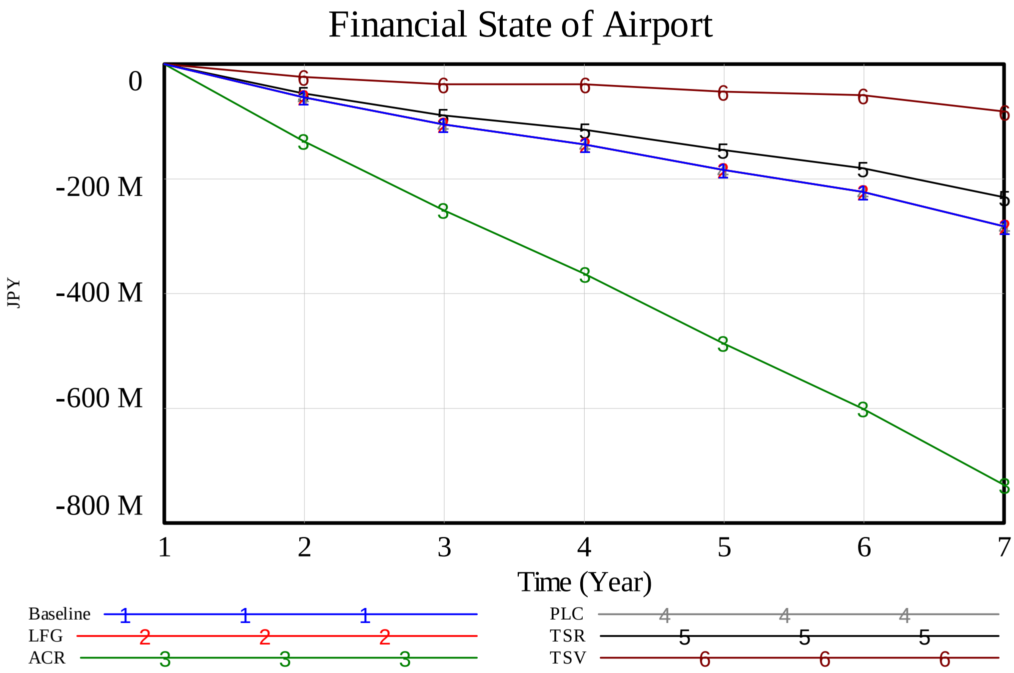


Fig. 6.13 Financial State of Airport (Non-aeronautical revenue included)

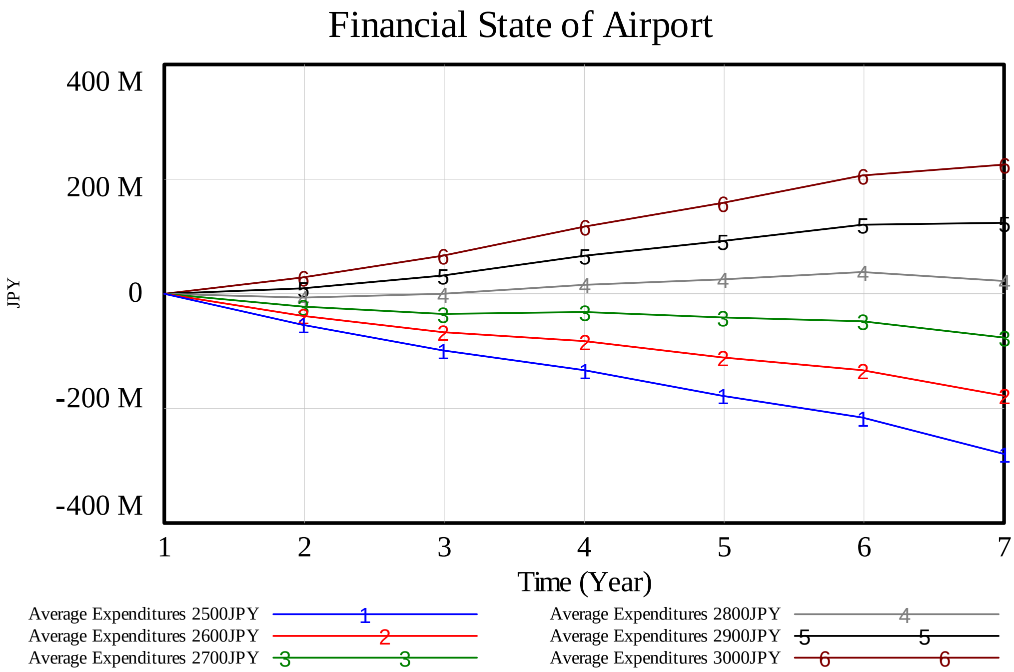


Fig. 6.14 Financial State of Airport (Average PAX Expenditure Increase)

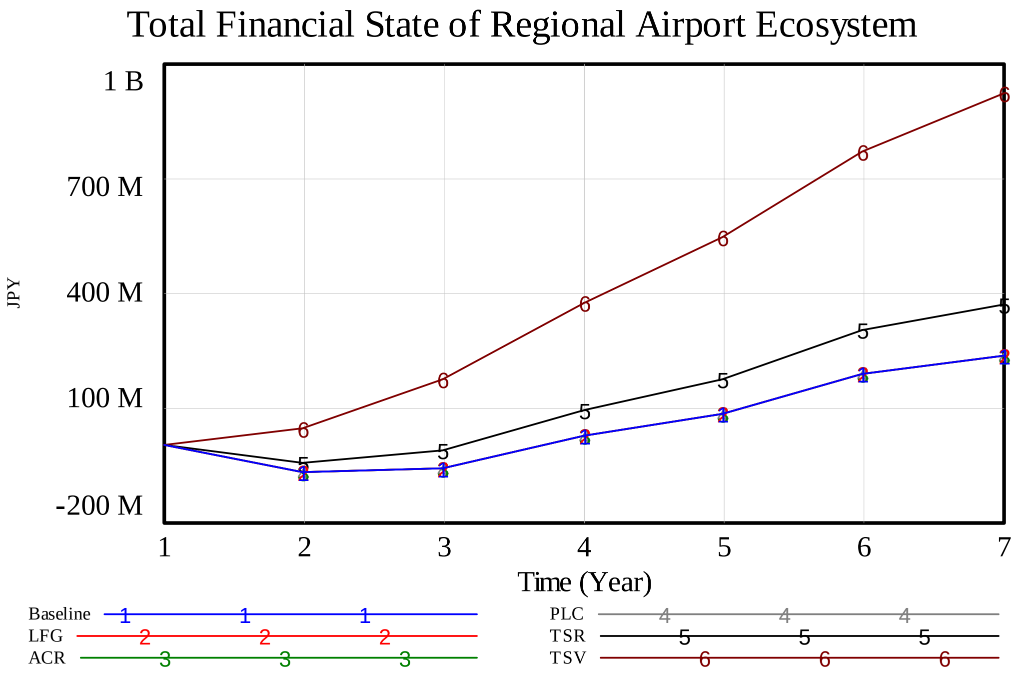


Fig. 6.15 Total Financial State of Regional Airport Ecosystem

(Non-aeronautical revenue included)

6.7. Chapter Conclusions

This chapter examined the possibility of managing a regional air transport as an ecosystem. I have developed a system dynamics model to simulate the impact of five management strategies on the entire ecosystem. The major findings are as follows:

(1). Instead of subsidizing unprofitable regional airlines, subsidizing ticket prices better aids the viability of the regional air transport ecosystem, primarily through the multiplier effects of attracting more passengers.

(2). Ticket subsidies require greater government expenditures than other strategies but stimulate the highest returns to government, mainly due to the cash feedback inside the ecosystem, from passengers to government, through tax revenue.

(3). Ticket subsidies for visitors have a greater effect than subsidies for residents. It seems somewhat unreasonable to provide benefits to non-taxpayers from local governments, but visitors provide multiple economic benefits to local communities, including increases in spending and tax revenues.

(4). Non-aeronautical revenue is critical for the commercial viability of regional airports. Without an integrated management of airport facilities under one entity, it will be difficult to achieve the commercial sustainability of the entire ecosystem.

The findings provide a new perspective on regional airport management based on mutualism. The benefit of the ecosystem viewpoint is that it makes each stakeholder understand that no one can survive without the others, which leads to proactive and cooperative countermeasures. The findings enable local governments to make rational initial investments to attract potential inbound air passengers that will be reimbursed after a time delay by the passengers' local expenditures. Regional airlines will cease to seek financial support to manage their unprofitability only when local governments cooperatively pursue visitor demand creation. After understanding their isolation in the ecosystem, regional airports will proactively take the initiative to broaden the scope of their business and consider non-aeronautical revenues. These insights will lead them to proactively and cooperatively manage the entire ecosystem.

The research also contributes to the literature by presenting a methodology for designing symbiotic relationships among multiple business stakeholders. The main conventional ways of managing unprofitable regional airports are government subsidies and airport abolition. I have shown that the ecosystem approach using system dynamics visualises inter-dependency among the stakeholders. Although ‘cause and effect are often distant in time and space’ (Sterman, 2000, p. 11), my approach can examine the long-term performance of each stakeholder in the context of interactions within the ecosystem over time.

Surprisingly, with a few exceptions, Japan’s national and local governments are behaving contrary to these findings, by subsidizing airlines and local residents. Since ‘the problem for most regional air transport is the lack of substantial traffic which made commercial revenue generation difficult’ (Lei and Papatheodorou, 2010), the first step is to increase demand. The proposed simulation model will help regional air transport stakeholders design a symbiotic system that can balance benefits among all stakeholders and increase the viability of the system.

So far, I have discussed several problem-solving approaches to cope with the weaknesses of regional air transportation. Establishing a self-sustaining system requires that the system be based on its strengths rather than its weaknesses. The following chapter establishes a new *raison d’etre* for regional air transport systems.

(Intentionally Blank)

(Intentionally Blank)

Chapter 7. Air Transportation and Disaster

Chapter 7 discusses the challenges against disruptions of regional air transportation. One of the examples is a catastrophic natural disaster. I examine mainly a regional air transport system involving local inland cities in the Tohoku region, Japan. A great earthquake and tsunami occurred on March 11, 2011, from which I acquired many insights into the designing of a more self-sustaining regional air transport system. A case study method is applied to understand interactions of multiple air transport stakeholders under catastrophic circumstances. Previous chapters mainly aim at finding ways to manage unsustainable regional air transport system but in this chapter I focus on finding a new raison d’etre for sustaining it from societal perspective.

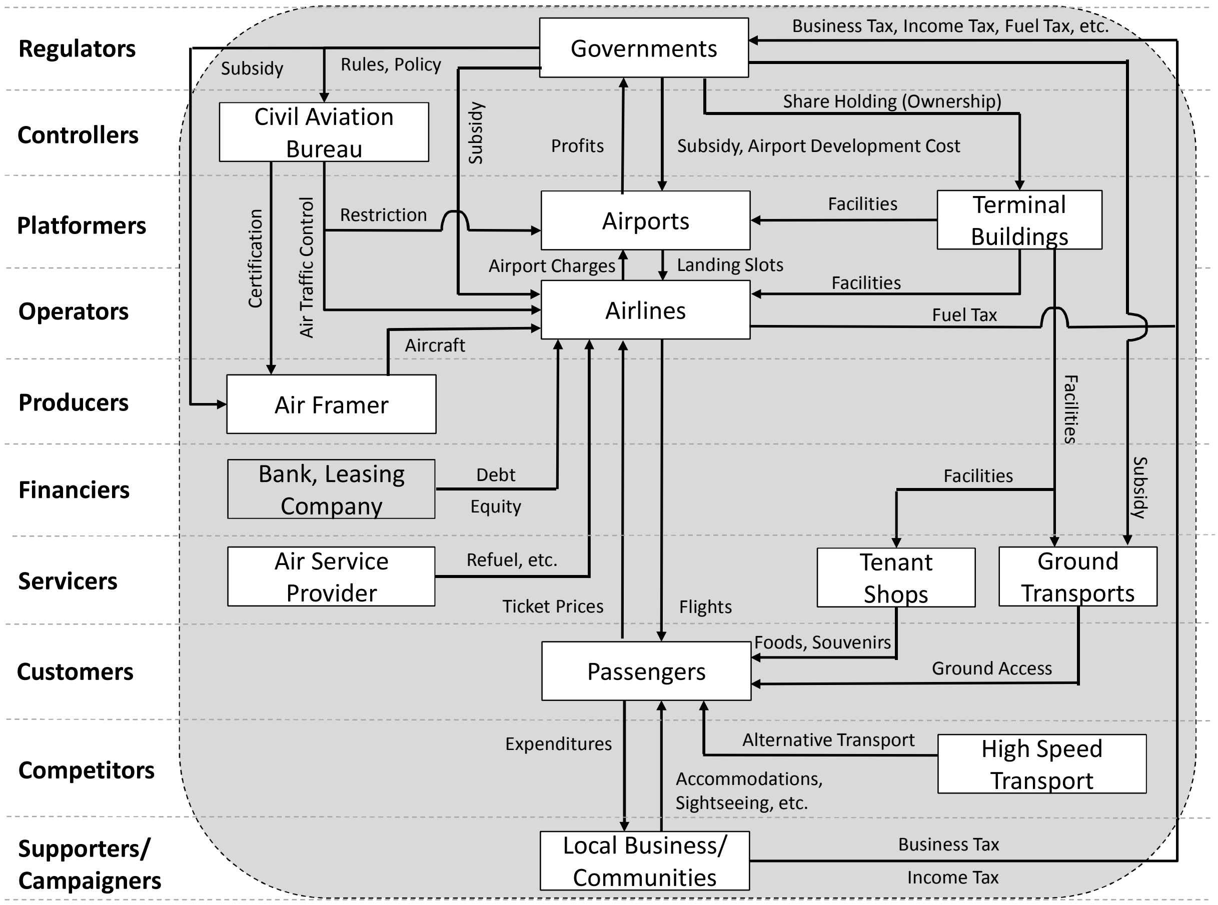


Fig. 7.1 Scope of Chapter 7 (all stakeholders except financers)

7.1. Introduction

A catastrophic earthquake and tsunami hit East Japan's coastal areas on March 11, 2011. According to the Fire and Disaster Management Agency of Japan (FDMA) approximately 20,000 people died or were listed as missing as of September 2011 (FDMA 2011), and more than 800,000 buildings were totally or partially destroyed. This catastrophic natural disaster severely damaged the regional transport system on the ground, in the ocean, and in the air.

One of the major blows to the transport system during the catastrophe was the loss of Sendai Airport (Fig. 7.2), located in the coastal area of the Tohoku region (see Fig. 7.3). An hour after the earthquake, the tsunami surpassed the runway and hit the airport terminal building. In addition, the airport facilities were damaged by consecutive earthquakes, and the ground access train to the airport was completely destroyed (Sendai Airport Transit Co. Ltd. [SAT), 2011); all airport operations were suspended on March 11, 2011. It took over a month before the airport partially reopened for special flights on April 13, 2011 and an additional four months before scheduled domestic flights resumed on July 26, 2011 (Ministry of Land, Infrastructure, Transport and Tourism (MLIT)). On September 25, 2011, more than half a year later, scheduled international flights resumed (MLIT).

Fig. 7.2 Sendai Airport on March 11, 2011
(Image source: AP/Kyodo)

The earthquake and tsunami also eliminated other means of transportation in the region, worsening the situation. For example, the blitz train at Tohoku Shinkansen suspended operations after the earthquake and did not resume until April 29 (MLIT). In addition, fuel shortages impeded highway bus services. The availability of vehicles and drivers was critical, however, in providing ground transportation in these turbulent circumstances (Yamagata Prefectural Government [YPG), 2011). The ground transportation system both to and from Sendai was completely inoperative. Because transportation systems play a fundamental role in an advanced economy, their failure causes substantial socio-economic losses (Cox et al., 2011).

Fig. 7.3 Airport location in the Tohoku region

After the loss of Sendai Airport, other regional airports had to maintain connections between the city of Sendai and other areas of Japan. Fig. 7.4 illustrates the numbers of air passengers at the nine airports in the Tohoku region from January to July 2011 (TCAB, 2011).

The data clearly indicate that air traffic at Sendai airport drastically dropped after the earthquake while that at the other airports in the region increased. To aid in rescue efforts, the airports of Yamagata, Fukushima and Hanamaki extended their operations to 24 hours per day to accommodate the increasing air traffic (MLIT). Graham and Guyer (2000) state that ‘all airports serve local markets and are dependent on the regions within which they are located’. When a major airport is congested, however, the role of local-to-local aviation services that bypass major airports becomes more important (Kita et al., 2005). During catastrophes, regional airports must serve more than their local markets. In 2011, regional airports compensated for Sendai’s lost capacity for a few months after the catastrophe. The regional airports thus aided not only their usual remote areas but also the large metropolitan areas; in times of need, then, a metropolitan airport’s capacity can be increased by making greater use of smaller, regional airports (Cidell, 2006).

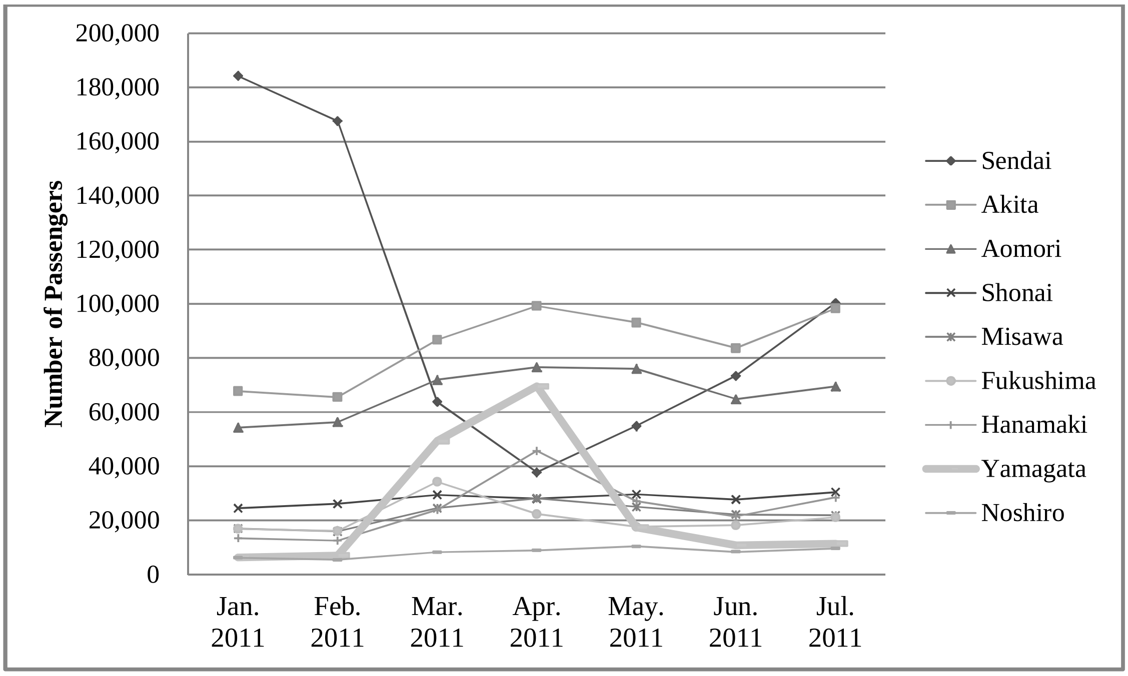


Fig. 7.4 Air traffic demand in the Tohoku region (January 2011–July 2011)

Data source: TCAB[3], MLIT[4]

[3]TCAB: Tokyo Civil Aviation Bureau

[4]MLIT: Ministry of Land, Infrastructure, Transport and Tourism

This chapter examines the role of regional air transport during catastrophes and proposes a management framework to cope with the sudden and drastic increase of air traffic after a disaster. In general, regional air transport is considered inefficient or unnecessary due to the thin and fluctuating air traffic demands (Graham and Guyer, 2000). However, our study highlights the added value of regional air transport for remote as well as metropolitan areas during disasters. In Japan, 38 airports are still located in lowland coastal areas (MLIT), where there is a high probability that a mega earthquake could occur within the next 30 years (National Research Institute for Earth Science and Disaster Prevention, 2010). I believe that the proposed management framework could improve the management of regional air transport during such catastrophes.

In April 2011, Japan's Port and Airport Research Institute (PARI) published a summary of the damages to Japanese airports (PARI, 2011), but few studies have analysed the impact of the East Japan earthquake and tsunami from an air transport perspective. Yoshitsugu (2011) investigates a Staging Care Unit (SCU) at Hanamaki Airport, while Hashimoto (2011) inspects the use of Fukushima Airport after the catastrophe. No research, to the best of my knowledge, has been conducted on Yamagata Airport, except for the technical report by YPG (YPG, 2011).

The remainder of this chapter is organised as follows. The section 7.2 explains the data for systems evaluation. The section 7.3 explains the methodology used in this research. The section 7.4 illustrates the case of the Yamagata Airport after the catastrophe and analyses the stakeholders' communication and management using the data collected from a series of interviews. The section 7.5 expanded the discussions to air transport system disruptions and collaborative management of airports under catastrophes. The ection 7.6 provides the conclusions and identifies the study's limitations.

7.2. Data for Systems Evaluation

The city of Sendai has the largest population in and is the economic and political centre of the Tohoku region (see Fig. 7.3). Sendai Airport plays an integral role in both passenger and cargo logistics. Table 7.1 shows a pre-earthquake analysis of air traffic market shares among the nine airports in the Tohoku region (Sendai, Akita, Aomori, Shonai, Misawa, Fukushima, Hanamaki, Yamagata, and Noshiro) in February 2011 (Tokyo Regional Civil Aviation Bureau [TCAB), 2011). Sendai's market share was 42.5% and 61.1% of domestic and international passengers and 63.5% and 92.2% of domestic and international cargo. The airport clearly functioned as a regional hub airport, and its sudden loss had a significant impact on the region's socio-economic situation.

Table 7.1 Market share of air traffic among nine airports in Tohoku (February 2011)

	Sendai	Akita	Aomori	Shonai	Misawa	Fukushima	Hanamaki	Yamagata	Noshiro
Domestic PAX[5]	42.5%	19.5%	14.9%	7.7%	4.7%	3.7%	3.5%	2.0%	1.5%
Int'l PAX[6]	61.1%	9.1%	15.6%	1.1%	0.0%	9.1%	2.2%	1.0%	0.8%
Domestic Cargo	63.5%	9.1%	16.7%	4.8%	4.2%	0.2%	1.1%	0.0%	0.3%
Int'l Cargo	92.2%	0.0%	0.2%	0.0%	0.0%	7.6%	0.0%	0.0%	0.0%

I analyse the regional air traffic data from the Tohoku region from January 2011 to July 2011 to identify the airport that played the most significant role in managing the catastrophe. Fig. 7.5 shows the conversion of the passenger air traffic data (see Fig. 7.4) into index format, 1.0 in January 2011. It shows that the air traffic demands at the Yamagata Airport in March and April 2011 increased 7.9 times and 10.9 times, respectively, over January 2011 (see Fig. 7.4). I anticipated that an excellent management practice was implemented to cope with the sudden and drastic air traffic expansion after the catastrophe. Thus, I selected Yamagata Airport for a detailed analysis.

[5]PAX: Passengers

[6]Int'l: International

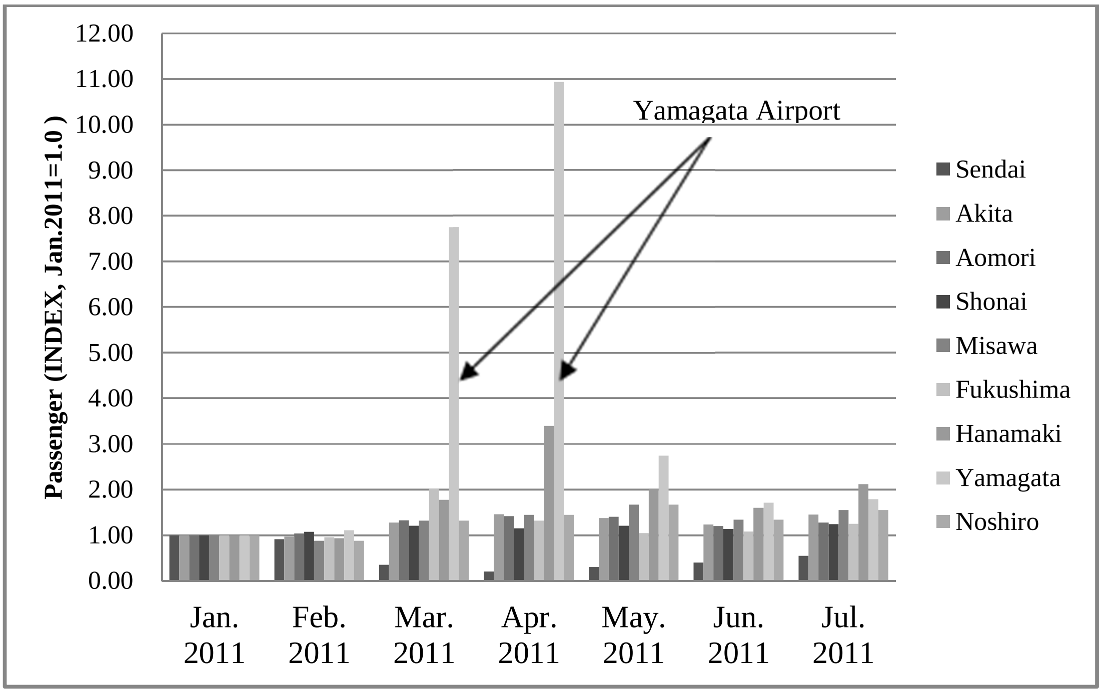


Fig. 7.5 Index analysis of the air traffic expansion in the Tohoku region after the earthquake (Jan. 2011=1.0)

(Data source: TCAB, MLIT)

7.3. Methodology

7.3.1. Systems evaluation process

As small airports in suburban areas have several social implications unique to the surrounding community (Bell et al., 2001), an analysis based on data alone would not be completely accurate. Hence, I have adopted a case study method using both historical data analysis and a series of semi-structured interviews with stakeholders involved in managing the catastrophe. Fig. 7.6 shows the systems evaluation process applied in Chapter 7. First, I analysed the regional air traffic data from the Tohoku region to identify which airport played the most significant role in managing the catastrophe. I anticipated that excellent management practices occurred at the airport after the catastrophe, thus making it suitable for the interviews.

Second, I conducted face-to-face, semi-structured interviews with the stakeholders in and around the airport. I identified the following as the key regional air transport stakeholders: the airline, the airport office, the airport terminal building, the ground transport provider, the travel agency, and the local government. During a catastrophe, these transport stakeholders must quickly and simultaneously respond to a progressive series of events, satisfying the diverse needs of both air and ground passengers. Such events demand extraordinary performance by staff, which is not officially recorded but retained only in the stakeholders' minds. Thus, I consider a semi-structured interview the appropriate tool for gathering the relevant information.

Third, I visualized inter-stakeholder communications before and after the catastrophe using a directed graph. The complexity and dynamics of a regional air transport system can be understood more easily by visualizing the situation (Nucciarelli and Gastaldi, 2009). Moreover, the visualization enabled us to analyse the structure adopted during the catastrophe. Nidumolu et al. (2007) have developed a Stakeholder Communication Matrix (SCM) that uses an adjacency matrix to visually analyse inter-stakeholder communications. The SCM identifies the strengths and weaknesses of the communication only between two stakeholders, however. I applied a directed graph with a node indicating a stakeholder in the transport system and an edge indicating the interaction among stakeholders, which is subdivided into request and response. When a stakeholder makes a request to another stakeholder, an edge is connected from its node to that of the stakeholder receiving the request. Using a directed graph enables to visualize the roles played by the stakeholders in managing the catastrophe, including the temporary roles played by the military, fire and disaster management departments, local community, and mass media. Finally, I discuss the implications for the successful management of air transportation during catastrophes. A new raison d'etre for sustaining regional air transport system is discussed from societal perspective.

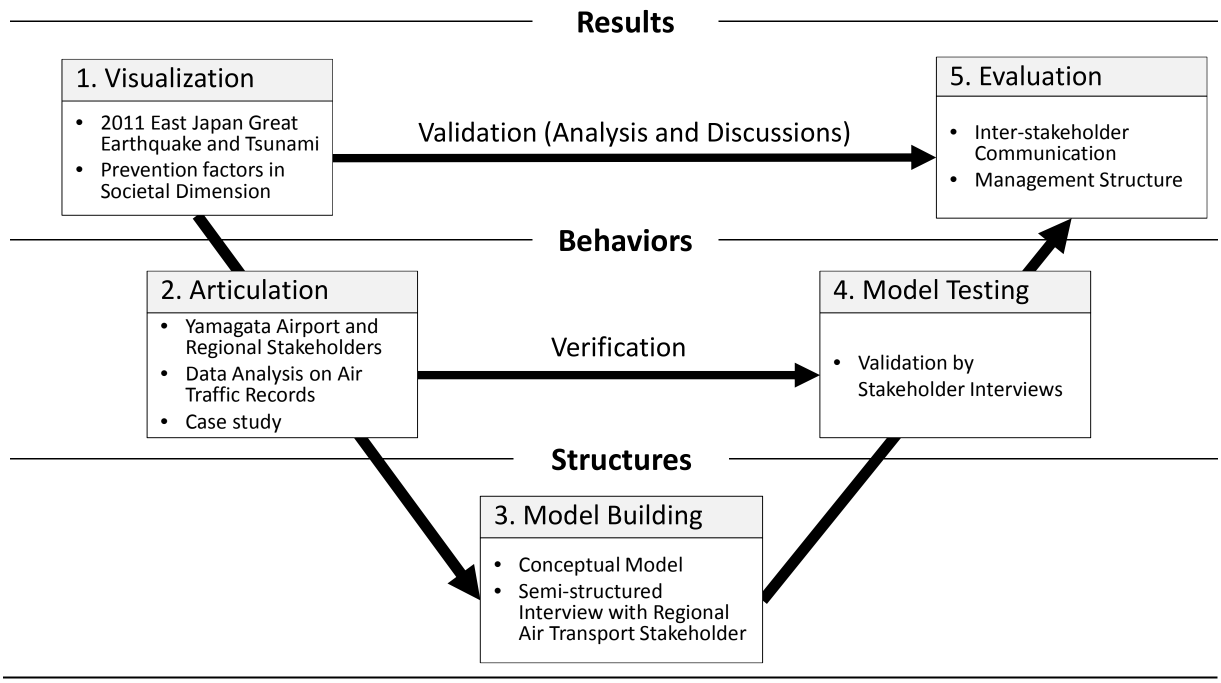


Fig. 7.6 Systems evaluation process (Chapter 7)

7.4. Results and Analysis

7.4.1. Yamagata Airport

In August 2011, I visited the YPG (Transport Policy Division and Airport and Port Division), the Yamagata Airport Management Office and the Yamagata Airport Building Co. Ltd. As ground accessibility is a crucial issue for the management of a regional airport (Papatheodorou and Lei, 2006), I interviewed a local bus company, Yamako Bus Co. Ltd. To analyse the supply side of air transport, I interviewed All Nippon Airways (ANA), which operated special flights to the Yamagata Airport from March 29, 2011 to May 22, 2011. I also discussed the issue with a local travel agency, Kinki Nippon Tourist, which coordinated ground transport services.

Yamagata Airport is located 20 kilometres north of the city of Yamagata, in an inconvenient and remote area (see Fig. 7.7). Since the opening of the airport in 1964, it has been owned and managed by the prefectural government (YPG, 2011). There is a 2,000-metre runway (see Fig. 7.7), and four scheduled flights per day (three to Osaka and one to Tokyo) are operated by JAL (Yamagata Airport Office (YAO), 2011). The annual air passenger traffic reached 742,291 in 1991 but then decreased dramatically to 156,231 in 2010, as shown in Fig. 7.6 (YPG, 2011). Okada et al. (2006) attribute the air traffic decline to emerging competition with the blitz trains of Shinkansen. Yamagata Shinkansen opened in 1992 and completed its railway extension in 1999. The blitz train travels from Tokyo station to Yamagata station within three hours. There is a second blitz train, Tohoku Shinkansen, that travels to Yamagata from Tokyo. In addition, highway bus services cost less than half the cost of air transport or the blitz train between Tokyo and Yamagata. Therefore, ground transport usually dominates the market, and air traffic demands were relatively low compared to the full capacity of the Yamagata airport before the catastrophe (YPG, 2011). As a result, Yamagata Airport was extremely underutilized (see Fig. 7.8).

Fig. 7.7 Yamagata Airport

(Source: TCAB, MLIT)

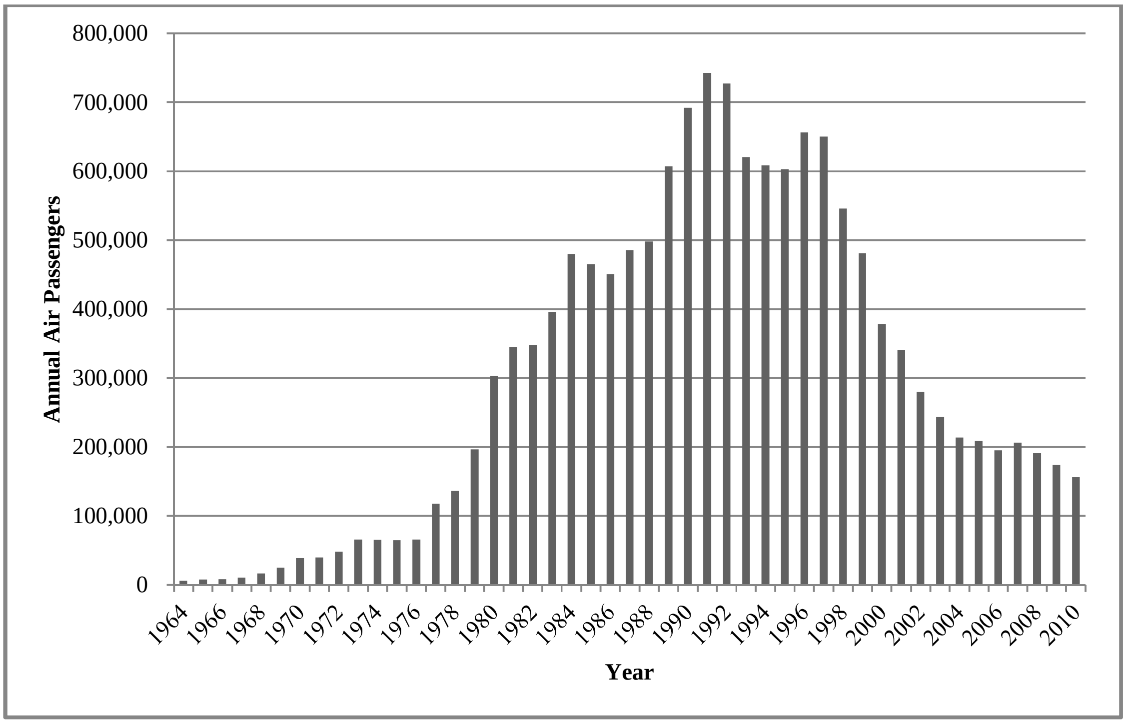


Fig. 7.8 Passenger air traffic at the Yamagata Airport (1964–2010)

(Data source: Yamagata Airport Office)

7.4.2.Stakeholder interviews

The East Japan earthquake and tsunami occurred at 14:46 on March 11, 2011. The Yamagata Airport immediately suspended all operations, cancelling flights to and from the airport (YPG, 2011). The drastic air traffic increase at the airport began the next day, on March 12, 2011. Fig. 7.9 shows the number of air passengers and the average load factor at the Yamagata Airport from March 11 to June 1, 2011 (YPG, 2011). In the first few days after the catastrophe, the high load factor indicates that the airport had a critical demand-supply condition. Passengers were brought to the Yamagata Airport for evacuation and rescued from the affected areas near the city of Sendai. The airlines could not quickly respond to the expanding demand, however, resulting in long queues of passengers at Yamagata Airport for flights to Tokyo and Osaka (YPG, 2011). From March 12 to 25, 268 standby passengers were forced to stay overnight at Yamagata Airport (Yamagata Airport Building Co. Ltd.).

There are three main reasons for the extraordinary concentration of air traffic at Yamagata Airport: 1) geography, 2) exposure to damage, and 3) underutilization. First, the airport is geographically situated close to the city of Sendai; moreover, divided by a mountainous area, the highway bus service usually travels between Yamagata Airport and Sendai in 75 minutes (Yamagata Prefecture). Second, because Yamagata Airport was not close to coastal areas, the earthquake and tsunami caused it no physical damage, except for a temporary blackout after the earthquake (Yamagata Airport). Third, because the airport is located in a rural town away from the city and is thus underutilized, there was sufficient slot capacity to accommodate the increasing number of scheduled flights and special flights from other areas of Japan. Ironically, the primary disadvantage of the regional airport became the primary contributing factor in managing the catastrophe.

Air transport capacity was strengthened in three ways: 1) increased frequency, 2) an upsized fleet, and 3) the provision of special flights. For example, JAL increased its flight frequency from two to 18 flights per day between Tokyo and Yamagata and from six to 12 between Osaka and Yamagata. In addition, the airline temporarily used Boeing 767s with 261 seats instead of its usual regional jets with 50 seats. In addition, JAL and Air Do (ADO) each provided four special flights per day between Sapporo and Yamagata, and All Nippon Airways

(ANA) provided four special flights per day between Osaka and Yamagata and two special flights per day between Chubu and Yamagata (YPG, 2011). According to ANA, the temporary fleet allocation was not particularly difficult because all flights to Sendai Airport had been cancelled for a month.

The air traffic expansion helped stabilize the recovery of other means of transportation. For example, the Yamagata Shinkansen resumed on April 12, 2011, and Sendai Airport partially reopened for special flights on April 13, 2011. Furthermore, the number of special flights at Sendai Airport increased after April 21, 2011 and the Tohoku Sinkansen resumed operations on April 25, 2011 (Yamagata Prefecture). The aggregate volume of air passengers at Yamagata Airport dramatically decreased (see Fig. 7.9), and the average load factor decreased along with the decrease in air passenger volume. Subsequently, the airlines gradually reduced their number of flights and downsized their number of aircrafts until the aggregated average load factor returned to break-even levels. Because the air traffic expansion was a temporary phenomenon and the airport was normally underutilized, there was extraordinary cooperation among the regional air transport stakeholders.

In the interviews, all the stakeholders emphasized ‘transport responsibility’. In the Japanese work ethic, it is typical to express one’s loyalty to the primary mission. Local optimization occurs when each stakeholder prioritises his or her own concern over the global objective, inducing a company to appoint managers to local offices to solve conflicts of interest among members. In Yamagata, however, a strong sense of transport responsibility prevented the stakeholders from pursuing their individual concerns. Even under extreme resource constraints, stakeholders concentrated on maintaining transport services for the benefit of the passengers.

The stakeholders in Yamagata also shared information simply and visually. Amid the uncertainty after the catastrophe, information and decisions were revised daily. The YPG gathered information from all stakeholders and distributed only A4-size paper documents on which substitute transport measures were visually described (see Appendix 2). Local newspapers and broadcasting companies supported communication to passengers from outside the region. This type of simplified and visualized communication system enabled both passengers and transport stakeholders to understand the ‘big picture’ of the transport system without confusion.

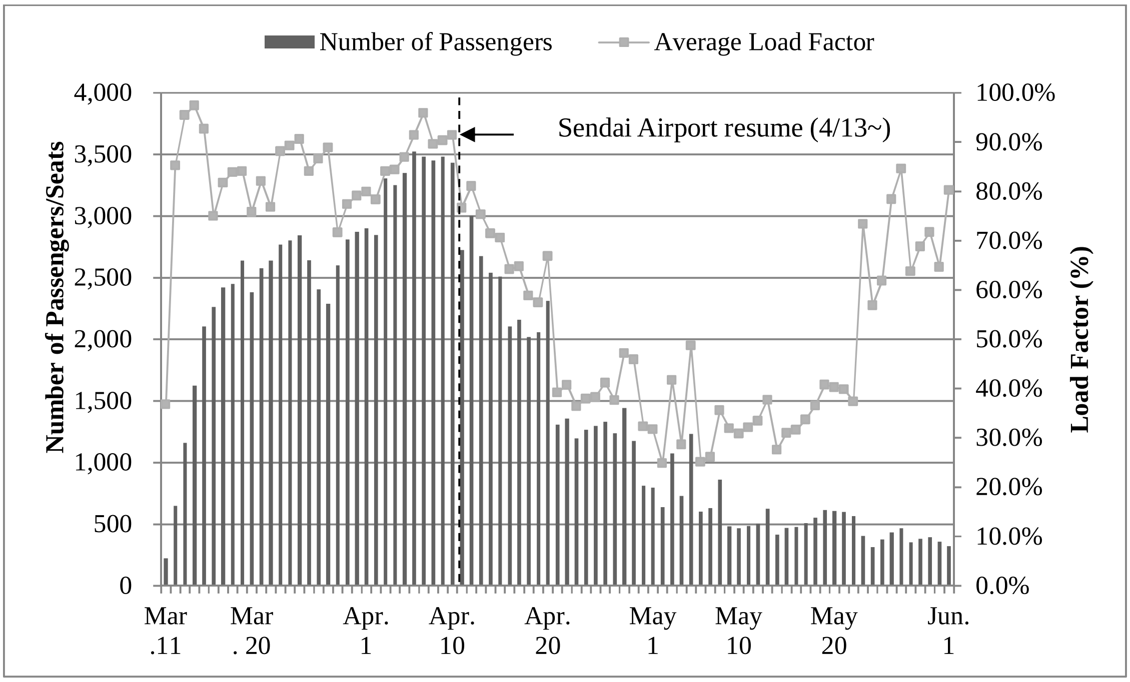


Fig. 7.9 Passenger air traffic at Yamagata Airport (March 11 to 30 June, 2011)

(Data source: YPG[7])

[7]YPG: Yagamaga Prefectural Government

7.4.3.Stakeholder communication

Fig. 7.10 depicts the visualized stakeholder communication before the catastrophe. I categorize the stakeholders into six groups: Airport, Air Transport, Passengers, Ground Transport, Central Government, and Local Government. In the normal situation, the inter-stakeholder communication was quite simple. Passengers (PAX) contact JAL for air transport service, a local bus company for ground transport service, and food and souvenirs shops for shops and restaurants (S&R). JAL contacts Airport Service Providers (ASP) for ground handling services, Yamagata Airport Office (YAO) for slot capacity allocation, the Airport Terminal Building (ATB) for service facilities, and the TCAB for air traffic control (ATC). The YPG directs the YAO and mutually communicates with the Ministry of Transport (MOT), which promptly directs the TCAB, the Regional Transport Bureau (RTB), and JAL.

The East Japan earthquake and tsunami drastically changed this situation. Yamagata Airport, that had operated 11.5 hours per day, suddenly switched to 24-hour operations on the morning of March 12, 2011 to cope with the expanding air traffic requirements. Fukushima and Hanamaki Airports also converted to 24-hour operations in the Tohoku region. Fig. 7.11 describes the stakeholder communication of Yamagata Airport after the catastrophe. Due to the situation, several new stakeholders were added, such as additional airlines (ANA and ADO), travel agencies (TRA), mass media (N&B), foreign governments, community governments (CGV), and other central government institutions.

Inter-stakeholder communication became more complex as the number of stakeholders increased. For example, because the U.S. Military Force (USF) and the Japan Self Defense Force (JPF) requested the use of Yamagata Airport for rescue services and emergency logistics, YPG had to consult with several CGV and local residents (CRS) around the airport. The Ministry of Foreign Affairs (MOF) intervened because the U.S. activities were conducted on the basis of an inter-governmental treaty. In addition, the FDMA requested 10 slots at Yamagata Airport for rescue helicopters sent from other prefectural governments (OPG). This helicopter slot domination became another constraint for mass media, which otherwise would have preferred to use their own helicopters for the live broadcasting of disaster situations.

Another difficulty was the integration of the expanded air transport demand and the ground transport capacity. Because most passengers were travelling to and from the affected areas, it was critical to provide direct ground access from Yamagata Airport to the city of Sendai. Unfortunately, no such connection existed before the catastrophe. The train service between Yamagata and Sendai stopped because of the earthquake (YPG, 2011).

There were two challenges for local stakeholders in providing extra transport services. The first was the scarcity of operational resources; the small local bus companies could not afford to hire extra bus drivers and vehicles for the emergency. In addition, the earthquake destroyed highway logistics, and there was an extreme shortage of gasoline fuel throughout Japan. The bus companies also had to cope with expanded ground transport requests within Yamagata. However, this was eventually solved by collaborating with other bus companies in nearby prefectures.

The other difficulty was the navigation of legal regulations. The law does not allow a bus company to operate a new scheduled transport service without official permission from the RTB if it is a commercial service. Therefore, the bus company collaborated with a local travel agency, which rented vehicles and drivers from the bus company and provided a 'commercial tour service', instead of a scheduled transport service from Yamagata Airport to the city of Sendai for air passengers. This idea was conceived and implemented because of collaborative management.

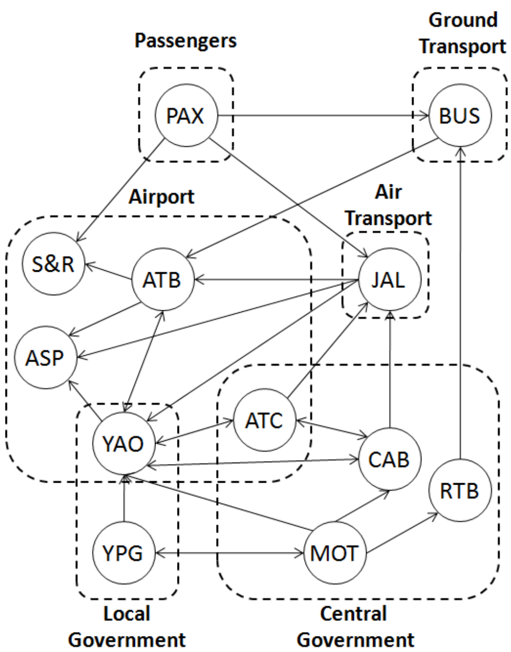


Fig. 7.10 Stakeholder communication matrix (before the catastrophe)

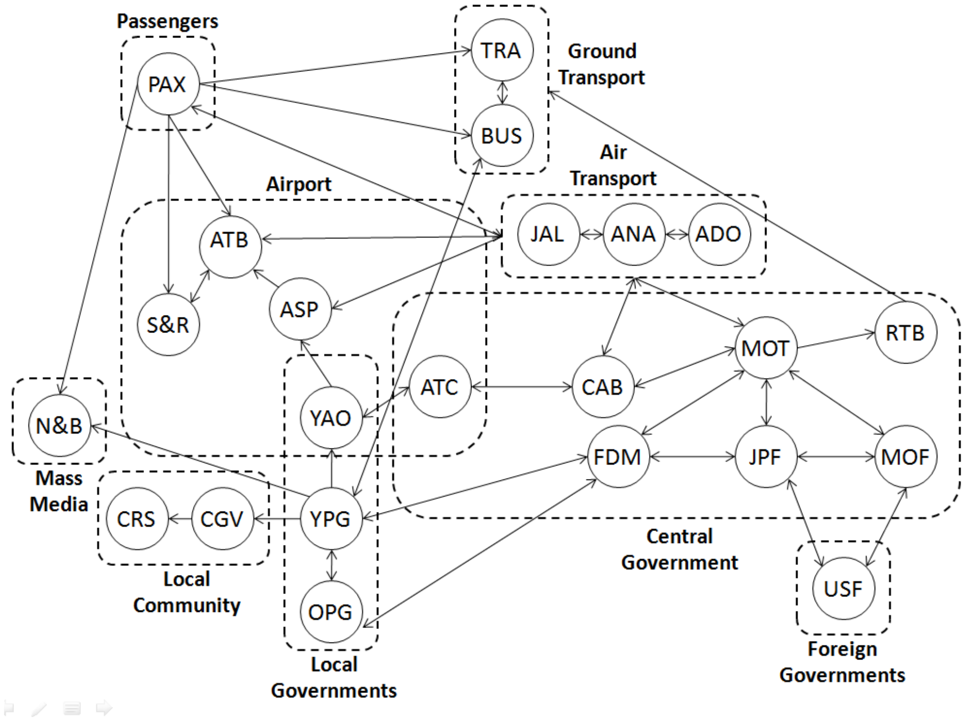


Fig. 7.11 Stakeholder communication matrix (after the catastrophe)

7.4.4.Management structure

The stakeholder communication analysis shows that the regional air transport stakeholders, both ordinary and temporary, collaborated to manage the catastrophe despite resource constraints to provide extra transport services. An interesting finding was that a clearly defined leadership structure to manage the situation was non-existent in the transport system before the catastrophe. In other words, intangible leadership arose without a leader to cope with the sudden and drastic expansion of air traffic after the event.

During other natural disasters, an Incident Command System (ICS) has been used for command and control situations (Urakawa et al., 2008). In the 2005 Hurricane Katrina disaster, local U.S. governments adopted ICS procedures (Kondo and Nagamatsu, 2007). A hierarchical management structure (as shown in Fig. 7.12) is considered more effective for gathering and distributing information among stakeholders.

The YPG played a partial role in facilitating the inter-stakeholder communications after the earthquake and catastrophe. For example, the YPG supported the registration of a direct bus service from Yamagata Airport to the city of Sendai (it would have otherwise taken a much longer time to obtain permission). The multiple stakeholders did not establish a vertical, pyramid management structure, however (see Fig. 7.12). On the contrary, they attempted to manage the situation on the basis of horizontal relationships among stakeholders (see Fig. 7.13). The problem with such a horizontal management structure is that it easily falls into local optimization (Kawai, 2004) because each stakeholder has its own concern, making conflicts of interest among stakeholders inevitable.

Nevertheless, a horizontal management structure can work effectively, even when there is no relevant manual. During a catastrophe, each transport stakeholder continuously faces unexpected events. In the case of Yamagata, the sudden near 11-fold increase in civilian air traffic and the U.S. military's operational requirements were phenomena beyond comprehension for the small airport stakeholders in the remote areas. The pre-defined manual did not address the prompt decision-making required in the turbulent circumstances following the catastrophe.

In addition, I recognize the limitations of the horizontal management structure during a catastrophe: it is unlikely to work when the objective is unclear. All stakeholders must hold a shared objective on the basis of which decisions are made. In the case of Yamagata, the objective was defined simply as 'minimizing local retention at any specific point in the transport system'. Therefore, the stakeholders could focus on achieving the objective despite the resource constraints. However, stakeholders in a vertical management structure prefer to wait until directions are passed down from the top.

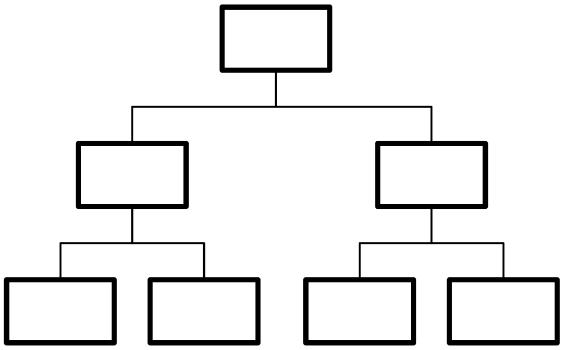


Fig. 7.12 Vertical Management Structure

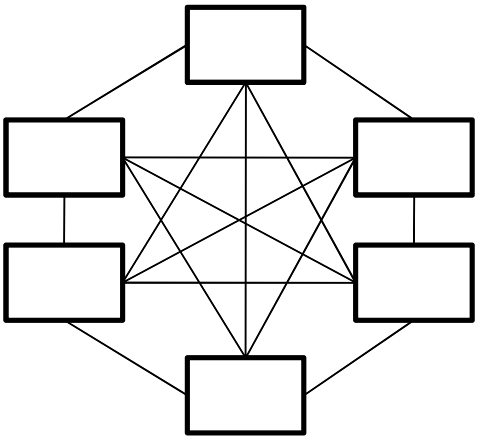


Fig. 7.13 Horizontal Management Structure

7.5. Discussions on Air Transport System Disruptions

Disaster varies in terms of cause (natural disaster vs. man-made), severity and extent of the event itself. Based on the extent of severity (number of casualties and amount of economic damages) and impact coverage (extent of affected areas), I categorized the disasters into local weather events (low severity, low coverage), regional weather events (low severity, high coverage), localized accidents (high severity, low coverage) and catastrophic disasters (high severity, high coverage). The complexity related to the disaster management plan, the amount of resources needed for the emergency, and the extent of stakeholder collaboration will highly depend on the type of disruptions or disasters that happened. I finally discuss the typology of disruptions (Fig. 7.14) in air transport system highlighting other disaster examples in overseas countries for applying the management implications from the 2011 Great East Japan earthquake and tsunami.

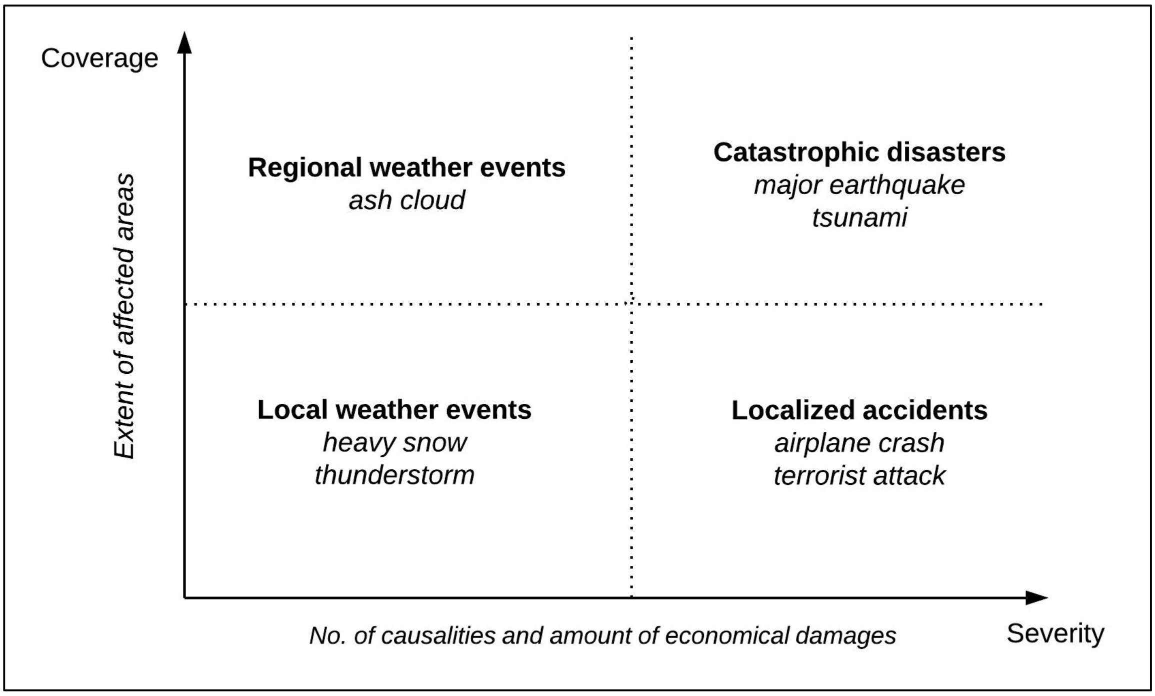


Fig. 7.14 Disruptions in the Air Transport System

The first category is local weather event (down left in Fig. 7.12). The examples are the heavy snow across the Europe and Thailand flood crisis, both happened recently in the year of 2011. At December 2011, at least four major airports in Europe were forced to close temporarily due to the heavy snow; Gatwick (UK's second busiest airport), Edinburgh (Scotland), Lyon-Bron (France) and Geneva (Switzerland's second biggest airport) (AOL News, 2010). In addition to that, only few flights were leaving London Heathrow (Europe's busiest airport) and at least one third of flights were cancelled in major hubs like Paris and Frankfurt, leaving many passengers stranded (BBC News Europe, 2010). European Commission issued critical note and warnings to the airports with regards to their way in handling the operations and demanded contingency plans to be prepared accordingly for the subsequent winters (EU Business, 2011). In a more recent event of 2011 Thailand flood crisis, for which a total damage of US$ 9.7 billion has been estimated (Human Development Forum Foundation, 2011), the local air transport system was also deeply affected. Don Muang Airport, Bangkok's second largest airport, which is mainly used for domestic flight, was completely flooded and the operations have since been moved to Suvarnabhumi, Bangkok's main international airport (Huffington Post, 2011).

The second category is regional weather events (up left in Fig. 7.14). Due to its broader geographical boundary, economic damage tends to become more serious in this category. The 2010 ash cloud due to the eruptions from Iceland's Eyjafjallajökull volcano has been recognized as one of the most disruptive events to hit air travel in years. The eruption was considered relatively minor in term of the Icelandic standards, yet it has caused tremendous amount of disruption to air travel across Western and Northern Europe. Approximately 20 countries closed their airspace, tens of thousands of passengers were left stranded across Europe and cost airlines an estimated of €150 million a day for a total of six days illustrate the extent of the impact on the economic and cultural events across Europe (Associated Press, 2010). There is a high possibility for a more powerful eruption to happen in Iceland, and the prediction is shown to be accurate by the occurrence of another eruption of Grímsvötn in May 2011. The volcano eruption was much more powerful than the one in 2010, as much as 100 times increase in the discharge rate and 3 times of the plume size, yet the disruption across Europe was relatively minor (Stevenson, 2012). While almost 8000 flights were cancelled on the first day of Eyjafjallajökull crisis, only approximately 500 flight cancellations were observed in the 2011 ash cloud crisis (Airport World, 2011). This showed evidence that airports and other actors had learned from the lessons from the previous events and have applied what they have learnt accordingly to improve the handling of the situations. The enormous disruption caused by Eyjafjallajökull 2010 eruption is mainly contributed by the terrible emergency planning, since at that moment there was limited information on the ash concentrations level that airplane could safely fly through that led to the relatively low limits being set. Since then, the rules have been changed, the science and the organizational structures in the industry have been improved, the collaboration between airports and airline partners have been progressed, which all have led to the low impact of the Grímsvötn situation (Stevenson, 2012).

The third category is localized accidents (down right in Fig. 7.14). While the previous two disruption categories have not led to the extensive damage in terms of casualties, a localized incident such as airplane crash and terrorist attack while restricted to the local area in terms of coverage, which may result in a large number of casualty damages. An example in this case would be the 2009 Turkish Airlines plane crash at Schiphol Airport, Amsterdam, where the plane carrying 127 passengers and 7 crews, has broken into three pieces, even though it did not catch fire at the end. The total casualties reported from this incident were 9 people died (3 of them were crews) and 84 people injured (BBC News, 2009). Amsterdam Schiphol airport, together with the local government and local emergency services, have handled this situation effectively corresponding to their emergency plan. All flights were suspended at the event of the crash, but the airport reopened shortly after. Since this event is of different nature (not natural disaster) than the one focused in this report, it will not then be discussed in further details.

The forth category is catastrophic disasters (up right in Fig. 7.14). Other than the 2011 Great East Japan earthquake and tsunami, there were several other natural catastrophic disasters happened in the last one decade that heavily affected the air transport system. The examples include the 2004 Indian Ocean earthquake and tsunami, as well as the 2010 Haiti earthquake. In all cases, the overwhelming challenges for the air transport system were related to the evacuation and the logistic delivery of the emergency aids. During the 2004 Indian Ocean earthquake and tsunami, a total of 12 countries are severely affected with Indonesia being the hardest-hit country and Aceh province in Sumatra Island being the worst affected area. Most of the evacuations from Aceh to the closest province of North Sumatra took place using air transport. However, the evacuation process was challenged by the damages and limited capacity at Aceh's airports

(Centre for Health Emergency Preparedness and Response, 2004). The emergency operations were then supported by the nearby Polonia airport at Medan, North Sumatra. The situation was further reflected by the statement of Colin Powell, US Secretary of State that the biggest problem was the logistical bottleneck of limited airport facilities (BBC News, 2005). A similar situation was experienced during the 2010 Haiti earthquake; the Port-au-Prince International Airport was too small and damaged to cope with the overwhelming number of incoming aid response. In view of the situation, the Santo Domingo airport at the neighbouring country of Dominican Republic provided the support by serving as an alternative route for aid, from which the cargo was to be transported to Haiti via the land route (BBC News, 2010). Nevertheless, due to the extent of the disaster and the unpreparedness of handling the emergency situation, both the airports as well as the Port au Prince-Santo Domingo route were soon become congested.

What is observed from the several cases is that the disastrous situations change dynamically. From decision-making perspective, there are some additional stakeholders that are going to be involved in the process under the emergency natural catastrophic disasters, besides those main stakeholders that we have been identified earlier during normal circumstances. These new stakeholders tend to be temporary in nature and play crucial roles in managing the disaster, which include military, fire and disaster management services, mass media and foreign governments. In view of this, it is important to ensure that the multi-issue decision-making process allows dynamicity in terms of the extent of actor involvement, such that stakeholder is able to enter (and leave) the decision making process at any time deemed necessary. The arrangement of decision-making process in rounds supports the dynamic nature, where the mixes of stakeholders change over time.

Other than that, what striking is the level of unpreparedness in dealing with catastrophic natural disaster, especially in term of air transport management for evacuation and logistic distribution. This can be explained through the unpredictability and the low frequency of natural disaster in such scale. In this case, the multi-issue decision-making process with all the stakeholders may also serve as the ‘preparation’ phase; to direct the perception of the stakeholders in the right direction and to create sense of urgency among them. The lack of urgency was cited as one of the factor that preventing the issue of airport collaborations during catastrophic disaster to be considered seriously among the stakeholders. It is the hope that the process will at least incentivize the start of the discussion about the issue at hand and will facilitate more prompt decision-making required during the turbulent situations following the catastrophic disaster.

7.6. Chapter Conclusions

In this chapter, I highlighted the added value of underutilized regional airports when managing catastrophes. Regional air transport is often considered inefficient or unnecessary due to thin and fluctuating air traffic demands (Graham and Guyer, 2000). In addition, public subsidies for unprofitable air transport services to remote regions have been criticized worldwide (Grubesic and Matisziw, 2011; Lian and Ronnevik, 2011). The rationale for such subsidies has primarily been the economic development of remote regions (Williams and Pagliari, 2004). In examining their role in managing catastrophes, I have found that such transport could contribute not only to remote regions but also to metropolitan areas. Cidell (2006) discusses such benefits in terms of capacity increases at metropolitan airports. My research highlights a new rationale for regional air transport that has been discussed from only an economic perspective.

During a catastrophe, regional air transport stakeholders must quickly respond to continuous events while simultaneously satisfying the diverse needs of air and ground passengers. Passengers are most highly satisfied when provided a means of transportation; following a catastrophe, however, they gradually begin to request faster, better, and cheaper means (YPG, 2011). Collaborative management among regional air transport stakeholders enhances a regional airport's responsiveness to a catastrophe and enables the stakeholders to provide alternative transport measures if a metropolitan airport becomes unavailable.

I found two implications while applying a horizontal management structure to the transport system during a catastrophe. Although these two implications are derived from the case analysis of Yamagata Airport in Japan, I believe other airports can also adopt the same perspective to cope with sudden and drastic increases in air traffic.

(1). Distribution of simplified information

Simple communication allows for the quick and efficient circulation of necessary information to multiple stakeholders. A visualized network diagram of alternative transport measures (see Appendix 2) in multiple languages is beneficial for passengers from outside the region, including foreigners.

(2). Sense of transport responsibility

Japan's unique work ethic of 'transport responsibility' greatly contributes to effective management during the catastrophe. Although all stakeholders had various resource constraints in the turbulent circumstances, after the catastrophe, they prioritized maintaining the transport system for societal benefit rather than pursuing individual concerns. This was a key in eliminating the local optimization of the transport system.

There are nine airports in the Tohoku region (see Fig. 7.3). This 'over-construction' has often been criticized when compared to the region's demographic and economic activity levels (Feldhoff, 2002, 2003; Yoshida and Fujimoto, 2004; Kato et al., 2011). Most of the airports have suffered low air traffic demand and unprofitability; some have faced severe competition from new high-speed trains. The research provides a new airport strategy for the Tohoku region as well as for other countries and regions where natural disasters may occur. Collaborating with other means of transport, regional airports play a critical role in sustaining various economic activities through logistics after a disaster.

PART 4

Scalability of Business Systems

(Intentionally Blank)

Chapter 8. Systems Evaluation on Competitiveness

In Part 4, Chapter 8 through Chapter 10, I discuss scalability of business systems. Scalability means that business systems are capable of growing in competitive market overtime. According to the Sun Tzu in ancient China, “a victorious army first wins and then seeks battles; a defeated army first battles and then seeks victory” (Cleary, 2005). It implies the importance of designing an intended success of business systems before entering into competition. Thus, I would like to present a framework for evaluating scalability of business systems (Fig. 8.1). It addresses an issue of how to grow business systems overtime. The framework is consisted of one thinking process and three evaluation components: multi-perspective thinking, competitiveness evaluation, uncertainty evaluation and business integration evaluation (Fig. 8.1). At the end of the processes, there are business systems that are to be managed throughout its lifecycle.

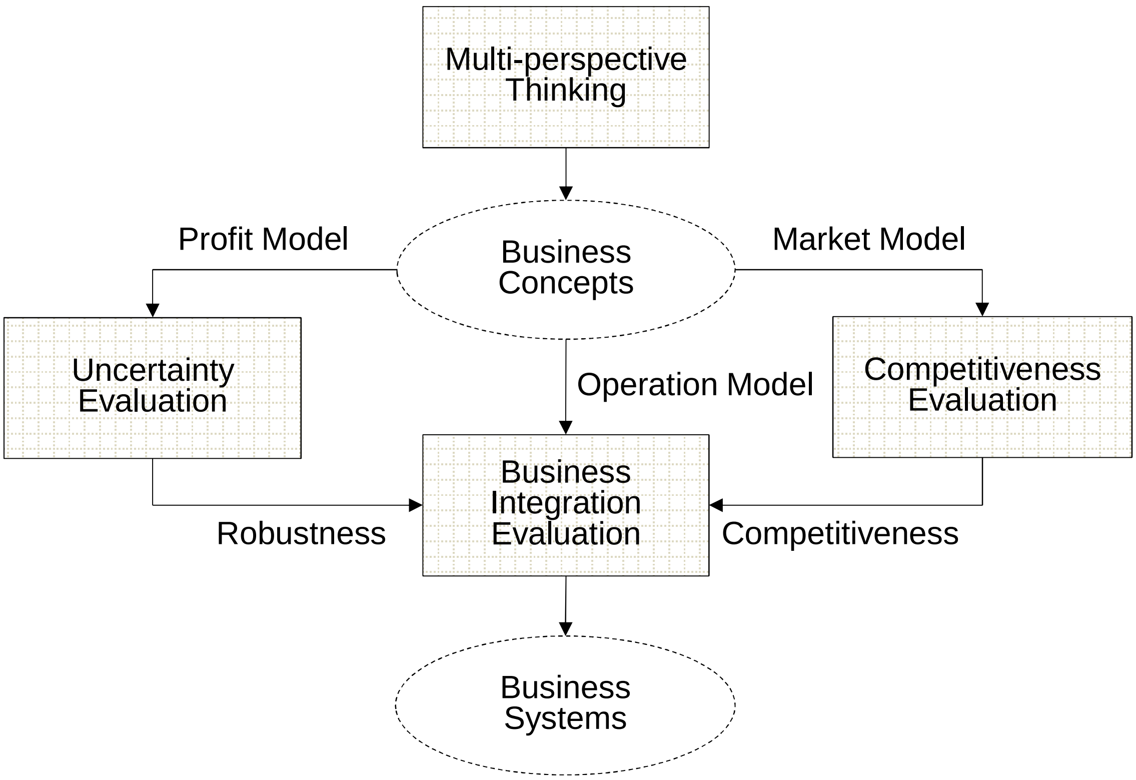


Fig. 8.1 A framework for business systems generation

The first step is multi-perspective thinking. Multi-perspective means that it utilizes several thinking measures with different characteristics such as logical thinking, system thinking and creative thinking. Logical thinking is used for decomposing businesses into its multiple elements which are interacting with each other. It is an effective thinking manner to deepen your analysis and to break a problem down into smaller pieces, namely, sub-problems (Nakano and Minato, Ch.2, 2012). System thinking is used for analysing causal relations of elements in business systems. Interactions bring about complex behaviour of a system so it is important to know its system structure by visualization (Nakano and Minato, Ch.2, 2012). Creative thinking is used for promoting extraordinary imagination beyond conventional ideas (Nakano and Minato, Ch.2, 2012). Utilizing the three different thinking measures integrally, several innovative business concepts are generated in the end.

However, just innovative business concepts are not good enough for successful business implementation. In order to grow up in a market, there are three issues to be examined for business systems: 1) competitiveness, 2) uncertainty and 3) business integration. Without establishing competitive advantage, a business cannot continuously stay in a market (Porter, 1985). Thus, it is preferable for a company to evaluate degree of competitiveness of its products or services before or during its market entry. But we lack systems evaluation method to do it. Furthermore, business is always associated with uncertainty. For example, new players might enter the same market or a new regulation might be introduced from governments. Macroeconomic factors such as recessions and currency rates fluctuation might affect business performance as well. It indicates that we are required to appropriately evaluate and manage such uncertainty for sustainable growth of a business. In addition, a business usually has a complex structure of multiple stakeholders and organizations. They are interacting with each other and bring about complex behaviours of business system. Without integrating business elements appropriately, continuity of business operation cannot be expected.

8.1. Chapter Introduction

In Chapter 8, I discuss systems evaluation of competitiveness of business systems. Fig. 8.2 shows the scope of the chapter in the evaluation framework (Fig. 8.1). It indicates that the market model such as competitors and segments are analysed based on the generated business concepts. It becomes an input to the competitiveness evaluation process. The output of the process is competitiveness of the business concept. It becomes an input to the business integration evaluation process in the end. Generally speaking, the more competitive business systems are, the more likely to grow up in a free economy market. In other words, evaluating degree of competitiveness is inevitable process for business systems to be scalable in a market.

The section 8.2 shows data for systems evaluation. I use the data of regional aircraft market in Japan. The section 8.3 explains the proposed method of competitive advantage matrix (CAM). The section 8.4 applies the method for evaluating an example of Mitsubishi Regional Jet (MRJ). Finally, I conclude the discussions and point out future works in the section 8.5.

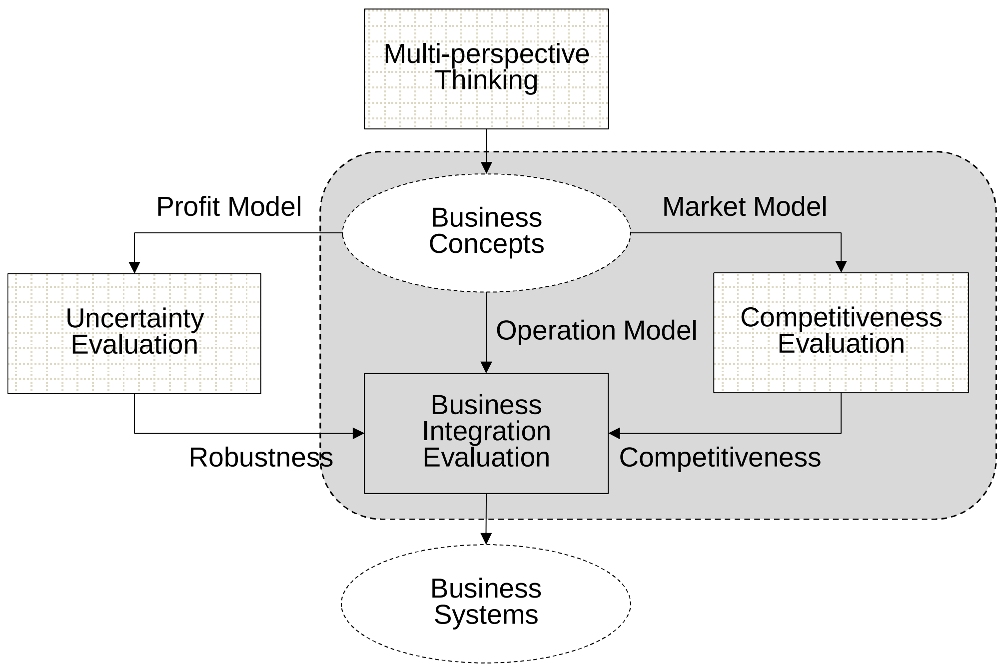


Fig. 8.2 Scope of Chapter 8 (Competitiveness Evaluation)

8.2. Data for Systems Evaluation

I conduct systems evaluation on regional aircraft market highlighting Japanese aircraft manufacturing company called Mitsubishi Aircraft Corporation (MAC). The company decided to launch a new regional jet aircraft with 70 to 90 seats in 2007. The aircraft is called Mitsubishi Regional Jet (MRJ). Fig. 8.3 shows the market share of small-size aircraft with less than 100 seats in Japan in 2007 (excluding private use), which was likely to be potential replacement target for MRJ (World Fleet June 2007). There were 80 small-size aircrafts in the market and 13 out of 80 are regional jet aircrafts called CRJ by Canadian Bombardier. The others are all turboprop aircrafts such as DHC-8 also by Bombardier, and Dornier 228, Fokker 50, Beechcraft 1900 and SAAB 340.

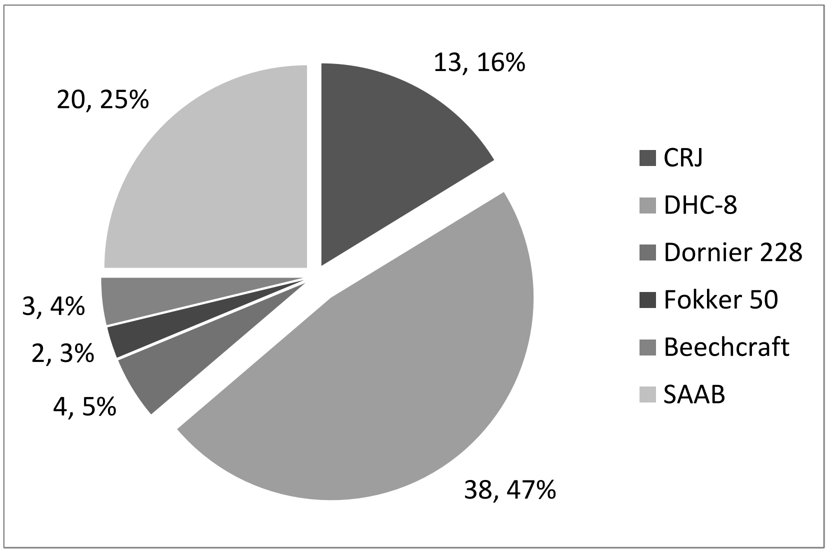


Fig. 8.3 Market share of regional aircraft in Japan
(Source: World Fleet June 2007)

The fact was that the Japanese market was competitive enough with more than 6 players inside and was increasingly dominated by Bombardier which occupied more than 60 percent of the market share. In fact, MRJ was required to enter and penetrate this competitive market.

Furthermore, the situation has changed even worse for MRJ since Japan Airline (JAL), the largest airline in Japan, had decided to introduce other regional jets called EMBRAER 170 manufactured by Brazilian company Empresa Brasileira de Aeronáutica in 2008. In addition, in 2009, a new airline called Fuji Dream Airline was established in Japan and it also decided to introduce EMBRAER 170 instead of MRJ. Therefore, MRJ is require to analyze its competitiveness in a market again so that it can figure out whether or not the current aircraft design is enough differentiated to be successful.

8.3. Methodology

8.3.1. Concept of Competitive Advantage Matrix (CAM)

I propose a method of competitive advantage matrix (CAM) in this research. There are two main features in the CAM analysis. First, it considers relative importance of each characteristic of a product in a market oriented context. It means that the CAM analysis enables to evaluate relative market competitiveness of a new product. The other feature is that it evaluates the product competitiveness from three different aspects; 1) technical excellence, 2) marketing strength and 3) social acceptance. The results acquire more reliability and objectivity rather than solely examining technical excellence as is often the case. Figure 8.3 shows the fundamental steps of the CAM analysis.

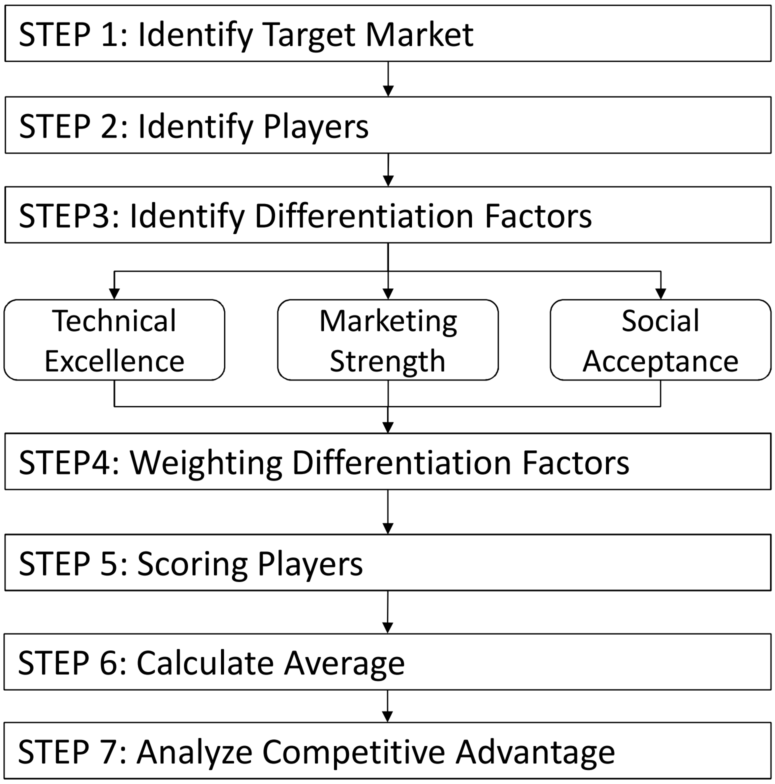


Fig. 8.4 Fundamental steps of CAM analysis

8.3.2. Modelling of CAM

The modelling process of CAM starts with identification of target market followed by identification of competing product and differentiation factors. Table 8.1 presents an example of CAM modelling using matrix-based software such as EXCEL. I explain each step more in detail.

Table 8.1 Framework of CAM Analysis

[STEP 1] Identify Target Market		**[STEP 4] Weight**	**[STEP 5] Player Evaluation**						**[STEP 6] Average Calculation**			**[STEP 7] Analysis of Product F**		
		Importance in Market	Segment Y			Segment Z			Segment Y Average	Segment Z Average	Market Average	v.s. A	v.s. Segt.Y	v.s. Market
[STEP 2] Identify Competing Players / **[STEP 3] Differentiation Factors**			Product A	Product B	Product C	Product D	Product E	Product F				$(F_i - A_i) \times W_i$	$(F_i - Y_i) \times W_i$	$(F_i - M_i) \times W_i$
Technical Excellence	Factor 1	w_1	A1	B1	C1	D1	E1	F1	Y1	Z1	M1			
	Factor 2	w_2	A2	B2	C2	D2	E2	F2	Y2	Z2	M2			
Marketing Strength	Factor 3	w_3	A3	B3	C3	D3	E3	F3	Y3	Z3	M3			
	Factor 4	w_4	A4	B4	C4	D4	E4	F4	Y4	Z4	M4			
Social Acceptance	Factor 5	w_5	A5	B5	C5	D5	E5	F5	Y5	Z5	M5			
	Factor 6	w_6	A6	B6	C6	D6	E6	F6	Y6	Z6	M6			
$i \in (1,2,3,\cdots n)$		$\sum_{i=1}^{n} w_i = 1$	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**YA**	**ZA**	**MA**	**Competitiveness**		

- Attractiveness [5: Very Attractive, 4: Attractive, 3: Moderate, 2: Less Attractive, 1: Least Attractive]
- Weight [5: Very Important, 4: Important, 3: Moderate, 2: Less Important, 1: Least Important]

STEP 1: Identify target market.

Identify target market to which your new product is expected to be delivered. It may be defined either by product type, customer type, region, country, generation, gender or combination of those. Appropriate segmentation is required.

STEP 2 : Idenfity players.

Identify competitors of your new product in a target market. It is necessary to find not only existing players but also potential competitors which are expected to enter the same target market in the near futgure. In order to maintain reliability of the analysis, it is desirable to identify more than 70 % of the competing players in terms of market share. Assume that there are several player (P_j) in a target market and the number of product is m.

In the example of Table 8.1, there are 6 players in a market and call them simply as Product A, Product B, Product C, Product D, Product E and Product F. There are two different segments in the market such as Segment Y and Segment Z. Product A through Product C are categorized into Segement Y and Product D through Product F are categorized into Segment Z in the assumption.

STEP 3 : Identify differentiation factor.

Identify characteristics that competiting products hold or expected to hold in the future. In the CAM analysis, it is required to identify differentiation factors in three different aspects ; 1) technical excellence, 2) marketing strength and 3) social acceptance. Degree of differentiation can be deffered in this stage. Assume that there are several differentiation factors (F_i) in a target market and the number of factors is n.

In the example of Table 8.1, I assumes that there are 2 differentiation factors in each aspect and call them simply as Factor 1 and Factor 2 for technical excellence, Factor 3 and Factor 4 for marketing strength, and Factor 5 and Factor 6 for social acceptance.

STEP 4: Weighting differentiation factors.

Evaluate importance of each differentiation factor (W_i) in terms of market competition, using a weighting scheme from 1 to 5 such as 5: Very Important, 4: Important, 3: Moderate, 2: Less Important, 1: Least Important. Weighting results should be in accordance with common sense of value in a target market. For such purpose, a focus group or weighted average of multiple answers from questionnaire is desirable. The results are relative and different from markets to market even if a product is the same.

In the example of Table 8.1, I simply set single letter code for each wighting result such as W1 for Factor 1, W2 for Factor 2, W3 for Factor 3, W4 for Factor 4, W5 for Factor 5 and W6 for Factor 6.

STEP 5 : Scoring identified player.

Evaluate attractiveness of each competing product against each differentiaton factor, using a scoring scheme from 1 to 5 such as; 5: Very Attractive, 4: Attractive, 3: Moderate, 2: Less Attractive, 1: Least Attractive. Then multiply the weight of each differentiation factor and the score of each player. Then sum all the multiplied scores up for each product. In the end, the calculated result of P_j in Eq. (8.1) shows you absolute competitive advantage of each product in a target market.

In the example of Table 8.1, I set single letter code for individual score of each product as A1, A2, A3, A4, A5 and A6 for Product A according to each differentiation factor. The same scoring process for Product B through Product F. I also sets single letter code for each final multiplied and summed up score such as P1 for Product A, P2 for Product B, P3 for Product C, P4 for Product D, P5 for Product E and P6 for Product F.

$$P_j = \sum_{i=1}^{n}(W_i \times A_i),\ i \in \{1,2,\cdots n\},\ j \in \{1,2,\cdots m\}$$

Eq. (8.1)

STEP 6: Calculate average.

Calculate scores of market average and segment average. This process enables not only to evaluate competitive advantage of a new product against specific competing product but also to estimate overall competitiveness of a product in a market or even in a segment as well.

In the example of Table 8.1, I set single letter code for average score in Segment Y as

Y1, Y2, Y3, Y4, Y5 and Y6 according to each differentiation factor. In the same way, single letter code for Segment Z is Z1, Z2, Z3, Z4, Z5 and Z6. Single letter code for Market Average is M1, M2, M3, M4, M5 and M6. I also sets single letter code for total sumed up scores such as YA for Segment Y Average, ZA for Segment Z average and MA for Market Average. The equations of caluculating Y1, Z1 and M1 are described as follows.

$$Y_i = \frac{A_i + B_i + C_i}{3}, i \in \{1,2, \cdots n\}$$

Eq. (8.2)

$$Z_i = \frac{D_i + E_i + F_i}{3}, i \in \{1,2, \cdots n\}$$

Eq. (8.3)

$$M_i = \frac{A_i + B_i + C_i + D_i + E_i + F_i}{\mathrm{m}}, i \in \{1,2, \cdots n\}$$

Eq. (8.4)

The euations of caluculating YA, ZA and MA are described as follows.

$$YA = \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{Y}_i , i \in \{1,2, \cdots n\}$$

Eq. (8.5)

$$ZA = \sum_{\mathrm{i}=1}^{\mathrm{n}} Z_i , i \in \{1,2, \cdots n\}$$

Eq. (8.6)

$$MA = \sum_{\mathrm{i}=1}^{\mathrm{n}} M_i , i \in \{1,2, \cdots n\}$$

Eq. (8.7)

STEP 7: Analyze competitive advantage.

The final step is to analyze competitiveness of a new product in a target market by comparing the results. Assume that your company is going to launch Product F and you would like to evaluate competitive advantage against market leader which is Product A. Then the equation of calculation is described in Eq. (8.8).

$$\text{Competitiveness of } \mathbf{Product\ F} \text{ against } \mathbf{Product\ A} = \sum_{\mathrm{i=1}}^{\mathrm{n}} \{(F_i - \mathrm{A}_i) \times \mathrm{W}_i\}, i \in \{1,2, \cdots n\}$$

Eq. (8.8)

In order to evaluate competitiveness of Product F against Segment Z to which Product F belongs, then the equation of calculation is described in Eq. (8.9)

$$\text{Competitiveness of } \mathbf{Product\ F} \text{ against } \mathbf{Segment\ Z} = \sum_{\mathrm{i=1}}^{\mathrm{n}} \{(\mathrm{F}_i - \mathrm{Z}_i) \times \mathrm{W}_i\}, i \in \{1,2, \cdots n\}$$

Eq. (8.9)

In order to evaluate competitiveness of Product F against a whole market in, then the equation of calculation is described in Eq. (8.10)

$$\text{Competitiveness of } \mathbf{Product\ F} \text{ against } \mathbf{Market} = \sum_{\mathrm{i=1}}^{\mathrm{n}} \{(\mathrm{F}_i - \mathrm{M}_i) \times \mathrm{W}_i\}, i \in \{1,2, \cdots n\}$$

Eq. (8.10)

If the score of your product is more than the market/segment average, then it means that your product is likely to acquire competitive advantage in the target market/segment. On the contrary, if the score of your product is less than the market/segment average, then your product is likely to fail in terms of market competition. Furthermore, if the score of your product is equal to the market/segment average, then competition is likely to reach “equilibrium”. In this case, without further differentiation, existing competitors are likely to have more advantage in terms of competition since they have already been recognized by customers in a market. In this way, you can evaluate whthere or not your new product is enough differentiated against existing competitors and against market/segemnet with the CAM analysis.

8.4. Results and Discussions

Table 8.2 shows the application results of the CAM analysis to the MRJ case. In STEP 1, I identifies a target market as Japanese small-size aircraft makrket with 30 to100 seats since these are the range of realistic replacement targets for MRJ. Then in STEP 2, the author identifies 6 players in Japanese market such as DHC-8 Q400, SAAB 340, Fokker 50, CRJ 200, EMBRAER 170 and MRJ 70. Then in STEP 3, the author identifies 15 differentiation factors in the market such as; A/C price, STOL Capability, Speed, Comfort, Cabin Quietness, Product Variety, Safety Reliability, Commonality, Fuel Consumption, Air Pollution, Maintenance Cost, Noise Level, Brand Image, Sales Channel and Customer Support.

After the identification process of the CAM analysis, then the author evaluate weight of each differentiation factor in STEP 4, considering how important each differentiation factor is to Japanese market, using weighting scheme from 1 to 5. The result is shown in Row A in Table 8.2. Then in STEP 5, I relatively evaluate each aircraft against each differentiation factor, using evaluating scheme from 1 to 5. The result is shown in Row B through Row G in Table 8.2. The weightings and the evaluations are the agreed scores which are based on the results of the multiple interviews and discussions with some of Japanese trading companies. They are the sales agents for the foreign aircraft manufacturing companies and thus know much about both aircrafts and the market.

Once finishing the evaluation of all aircrafts, then I calculate the score of market average and regional jet segment average in STEP 6. The result is shown in Row H through Row J respectively. Finally, in STEP 7, I calculate competitive advantage of MRJ against the market leader DHC-8 which is now occupying almost half of the Japanese market. I also calculate the score against regional jet segment average to which MRJ belongs and against total Japanese market average as well. The result is shown in Row K, Row L and Row L respectively.

As a result of the CAM analysis in Table 8.2, I conclude that MRJ is likely to face equilibrium of competition in Japanese market (0.0 point). In addition, MRJ is slightly less competitive against regional jet segment (-3.0 points) and even less competitive against whole market in Japan (-15.0 points). Therefore, the conclusion of the analysis is likely to recommend “redesign” of the aircraft so as to acquire additional differentiation.

Furthermore, the CAM analysis can be used to simulate how the competitiveness of a new aircraft changes in a target market if MRJ would improve or add some of the differentiation factors to the current configuration of the aircraft design. In addition, the CAM analysis makes it possible to simulate the impact of additional competitors’ entry into the market as well. For example, other new regional jets such as Russian Sukhoi Superjet or Chinese ARJ 21might challenge the Japanese market in the future. MRJ is able to further evaluate its competitiveness against such new competitors just by including these new foreign aircrafts in the CAM matrix. The point is that the tool can simulate potential actions and reactions of the competitors beforehand and thus enable to evaluate how competitors’ behavior affects competitiveness of your product in the market.

Table 8.2 Results of CAM Analysis (MRJ case)

		Weight	Evaluation						Average			Analysis		
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**
		Importance in Japanese Market	Turboprop (TP)			Regional Jet (RJ)			TP Segment	RJ Segment	Market	v.s. Leader	v.s. Segt.	v.s. Market
			DHC-8	SAAB	Fokker	CRJ	ERJ	MRJ				**(G-B)*A**	**(G-I)*A**	**(G-J)*A**
Technical Excellence	STOL Capability	3	3	5	5	2	2	3	4.3	2.3	3.3	0.0	2.0	-1.0
	Speed	4	3	1	1	5	5	5	3.3	1.7	3.3	8.0	13.3	6.7
	Comfort	2	3	3	3	4	5	5	3.8	3.0	3.8	4.0	4.0	2.3
	Cabin Quietness	2	4	2	1	3	3	3	2.7	2.3	2.7	-2.0	1.3	0.7
	Commonality	3	3	1	1	3	5	5	3.0	1.7	3.0	6.0	10.0	6.0
	Fuel Consumption	5	4	5	5	1	2	3	3.3	4.7	3.3	-5.0	-8.3	-1.7
	Maintenance Cost	4	4	4	4	2	2	2	3.0	4.0	3.0	-8.0	-8.0	-4.0
Marketing Strength	A/C Price	5	3	5	5	2	1	1	2.8	4.3	2.8	-10.0	-16.7	-9.2
	Product Variety	3	5	1	1	5	5	2	3.2	2.3	3.2	-9.0	-1.0	-3.5
	Sales Channel	5	5	3	1	5	5	5	4.0	3.0	4.0	0.0	10.0	5.0
	Customer Support	5	5	2	2	5	3	3	3.3	3.0	3.3	-10.0	0.0	-1.7
	Brand Image	3	1	3	1	1	3	3	2.0	1.7	2.0	6.0	4.0	3.0
Social Acceptance	Air Pollution	3	4	5	5	1	2	4	3.5	4.7	3.5	0.0	-2.0	1.5
	Safety Reliability	5	1	5	5	1	5	3	3.3	3.7	3.3	10.0	-3.3	-1.7
	Noise Level	5	4	5	5	1	3	3	3.5	4.7	3.5	-5.0	-8.3	-2.5
											Scores	**-15.0**	**-3.0**	**0.0**

8.5. Chapter Conclusions

Competitiveness is one of factors for business systems to be scalable in a free market. Therefore, I proposed a matrix-based approach to systematically evaluate competitiveness of a new product in a market oriented context. I believe that the benefits of the CAM analysis are to;

(1) Provide insights on whether a new product is likely to acquire competitive advantage against competing products, against segments and against markets at the same time, in a single matrix calculation, with enough differentiation in a target market, considering all aspects of technical, business and social factors.

(2) Enable to simulate future state of competitiveness of a new product, considering conceivable actions and reactions from current and potential competitors such as new market entrants and further enhancement of the competitors.

(3) Visualize decision making process of a product design in the process of development so that all the stakeholders can participate in the discussion.

The current CAM analysis represents only a simple decision making tool for designing a successful product differentiation. The tool is useful especially for a conceptualization phase of a new product development due to its simplicity and easiness of mastery. Future work must be done for enhancing rationality and objectivity of the scoring process in a matrix-based approach. It is also an important issue to evaluate the degree of “fit” between a target market and a new product as well.

(Intentionally Blank)

Chapter 9. Systems Evaluation on Uncertainty

9.1. Chapter Introduction

Business is always associated with uncertainty. For example, new players might enter the same market or a new regulation might be introduced from public sectors. In such cases, rules of competition are likely to be drastically changed. Furthermore, macroeconomic factors such as recessions and currency rates fluctuation affect business as well. It implies that evaluating competitiveness of business system (see Chapter 8) is not good enough for assuring business sustainability. Thus in Chapter 9, I discuss systems evaluation on uncertainty of business systems. Fig. 9.1 shows the scope of the chapter in the evaluation framework (Fig. 8.1).

In the following, I explain data for systems evaluation in the section 9.2. The section 9.3 explains the methodology used in the study. The section 9.4 shows the modeling process to quantify the business model for financial simulation. The section 9.5 analyzes the business using the matrix-based approach. Scenario Analysis and Monte Carlo Simulation are introduced to evaluate uncertainty. I conclude the discussions and point out future works in the section 9.6.

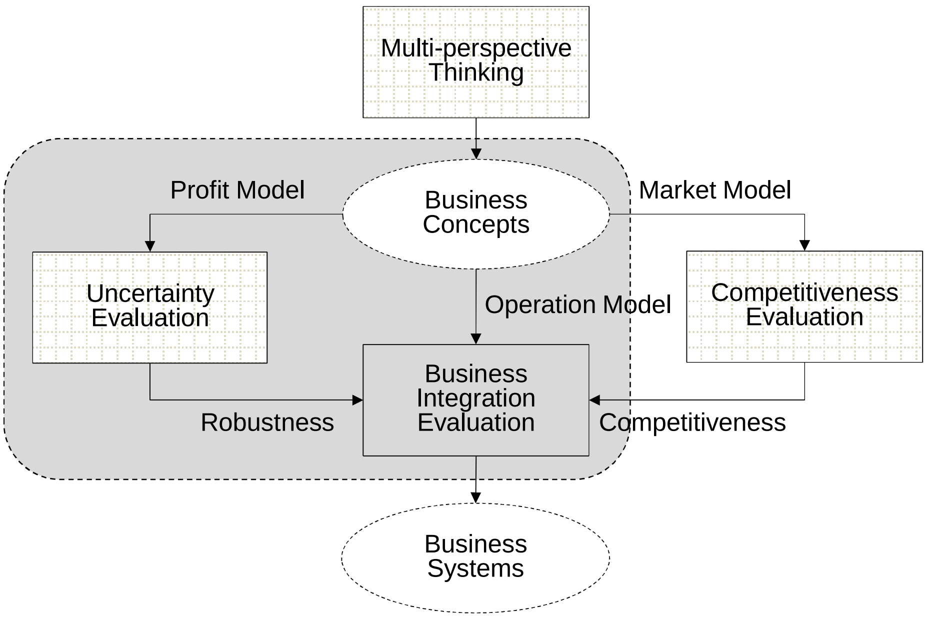


Fig. 9.1 Scope of Chapter 9 (Uncertainty Evaluation)

9.2. Data for Systems Evaluation

For evaluating uncertainty in business, in this chapter, I highlighted a business with an emerging technology. Emerging technologies has a lot of uncertainties both in technical and commercial perspectives and therefore is appropriate for examination. More specifically, I highlighted Indoor Messaging System (IMES) in this study. IMES is a newly developed technology which enables to provide location-based information service both inside and outside building seamlessly. Among various existing technologies for the same type of service (Marco, A., Casas, R., Falco, J., Gracia, H., Artigas, J.I., Roy, A., 2008), the strength of the IMES is its compatibility with GPS protocol (Kogure, Maeda, Ishii, Manandhar and Okano, 2008). For example, with the IMES technology, a GPS-equipped cell phone does not require any additional equipment to receive location information even inside the building or underground, where GPS signal cannot reach today. However, such an excellent technology does not always become the winner of the market (Polk, R., Plank, R., Reid, A. 1999). A feasible and sustainable business model must be designed beforehand in order for a newly developed technology to be a commercially scalable in a market.

I assume that the location-based information service with the IMES technology would be provided at one of the biggest outlet malls in Japan called Karuizawa Prince Shopping Plaza. Table 9.1 showed the installation plan for the IMES transmitters based on the analysis of the facilities of the mall. 1 IMES transmitter was assumed to be installed at each shop, corridor (in front of every shop), information centre, toilet, nursing room, entrance, exit, elevator, corner, coin locker, shuttle bus station, smoking room, public telephone, cash dispenser, car parking and bicycle parking. In total, 744 IMES transmitters were necessary at the outlet mall for the IMES service operation. The numbers are analyzed based on the on-site observation at the site.

Furthermore, through the discussions after the on-site observation, I identified 18 parameters associated with the business systems: Number of Tenant Shop, IMES Utility Fee, IMES Service Adoption Rate, Number of IMES Transmitter, Transmitter Unit Price, Transmitter Installation Cost, Transmitter Maintenance Cost, Transmitter Electricity Cost, System Development Cost, System Operation Cost, System Improvement Cost, Margin to Building

Manager, Administration Cost, Project Duration, Discount Rate, Tax Rate and Depreciation.

Table 9.1 IMES Transmitter Installation

Installation Spots in the Mall		**Number**
Shops		208
Corridor (in front of every shop)		208
Information Centre		3
Toilets		10
Toilets for Disabled Person		8
Nursing Rooms		6
Entrances/Exits		9
Elevators		5
Corners		247
Coin Lockers		7
Shuttle Bus Stations		2
Smoking Rooms		8
Public Telephones		5
Cash Dispensers		2
Car Parking		11
Bicycle Parking		5
	Total	744

9.3. Methodology

I introduce a matrix-based approach to analyze the sources of uncertainty (Fig. 9.2). The matrix is consisted of two axes of controllability and variability. ‘Fixed and uncontrollable’ parameters should be treated as constraints. Best guess could be reasonably used for the ‘fixed and controllable’ parameters. On the other hand, Scenario Analysis would be appropriate for ‘variable and controllable’ parameters. Assumptions must be set for ‘variable and uncontrollable’ parameters so as to reflect uncertainty. The benefit of the approach was the reduction of time and effort for the analysis by treating some parameter as predominantly given.

		Variability	
		Variable	Fixed
Controllability (by a company)	Controllable	Scenario	Best Guess
	Uncontrollable	Assumption	Constraint

Fig. 9.2 Matrix-based analysis for uncertainty evaluation

Table 9.2 showed the result of the matrix-based analysis. Among the 18 identified parameters (see Section 9.2), 5 parameters were considered as uncontrollable and fixed and thus should be treated as Constraints. 1 parameter was considered as controllable and fixed and thus should be defined by Best Guess. 8 parameters were considered as uncontrollable and variable and thus should be defined by assumption. 3 parameters were considered as controllable and variable and thus should be analyzed based on scenario. Finally, I could choose the 3 parameters which were appropriate for Scenario Analysis; System Development Cost, Margin to Building Manager and IMES Utility Fee. These parameters depend either on a company’s investment decision or on pricing strategy and thus it is possible for a company to decide them at company’s disposal. In the following, the authors evaluated the flexibility of the IMES business in two different aspects; 1) cash outflow, which would affect the cost of the business and 2) cash inflow, which would affect the revenue of the business.

Table 9.2 Result of Matrix-based Analysis

		Fixed	Variable	Controllable	Uncontrollable	**Results**
Number of Tenant Shop		○			○	**C**
IMES Utility Fee	Initial Annual		○	○		**S**
IMES Service Adoption Rate			○		○	**A**
Number of IMES Transmitter		○			○	**C**
Transmitter Unite Price			○		○	**A**
Transmitter Installation Cost			○		○	**A**
Transmitter Maintenance Cost			○		○	**A**
Transmitter Electricity Cost			○		○	**A**
System Development Cost			○	○		**S**
System Operation Cost			○		○	**A**
System Improvement Cost			○		○	**A**
Margin to Building Manager			○	○		**S**
Administration Cost		○		○		**B**
Project Duration		○			○	**C**

Discount Rate		○		○	**A**
Tax Rate	○			○	**C**
Depreciation	○			○	**C**

A: Assumption **B**: Best Guess **C**: Constraint **S**: Scenario Analysis

9.4. Model Building

9.4.1. Business model overview

Business to Business (B to B) model was adopted in the simulation as shown in Fig. 9.3. The interactions of business stakeholders are visually described to facilitate financial modeling with cash flow consideration. First of all, a company was assumed to purchase 744 IMES transmitters from the IMES transmitter manufacture to install them at the outlet mall. Then, the company would provide the location-based information service to the tenant shops inside the mall. In return, the shops would pay the IMES utility fee to the company in addition to the rent to the outlet mall manager. The outlet mall manager would receive profit margins from the company in return for permitting the IMES transmitter installation at the mall. Finally, consumers would be able to receive commercial information (e.g. free coupons for shopping) via the IMES environment. Customers would be stimulated to purchase more goods and services at the mall due to the information provided by the IMES.

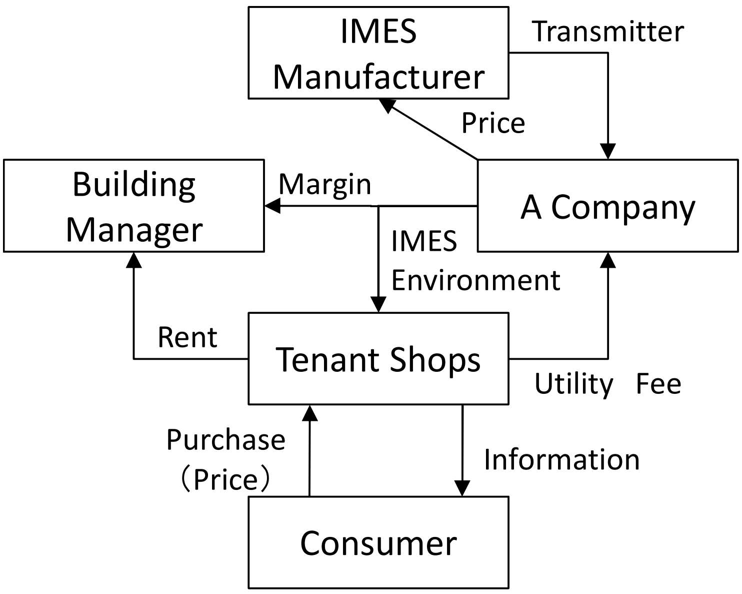


Fig. 9.3 Business Structure

9.4.2. Financial modelling

Annual revenue is calculated by multiple of the three parameters, Number of Tenant Shop, IMES Service Adoption Rate and IMES Utility Fee. The calculation is shown in Eq. (9.1).

$$\text{Annual Revenue}_{i,j} = TS_{i,j} \times UF_{i,j} \times AR_{i,j}$$

Eq. (9.1)

where i is year, j is location (e.g. Karuizawa Shopping Mall), $TS_{i,j}$ is the number of tenant shops in year i at location j, $UF_{i,j}$ is IMES utility Fee in year i at location j, and $AR_{i,j}$ is IMES Service Adoption Rate in year i at location j.

The IMES Service Adoption Rate ($AR_{i,j}$) is the ratio of the IMES service utilizing shops divided by the number of total tenant shops in year i at location j. The calculation is shown in Eq. (9.2). The ratio shows the average volatility of the service utilization, which in turn, would affect the revenue of the business. Since every shop would not necessarily use the IMES service throughout the 10 years due to economic downturns or simply reluctance, I introduce the concept.

$$\text{IMES Service Adoption Rate } (AR_{i,j}) = \frac{IMES\ Sevice\ Utilizing\ Shops\ in\ year\ i\ at\ location\ j}{All\ Tenant\ Shops\ in\ year\ i\ at\ location\ j}$$

Eq. (9.2)

Second, annual cost was calculated by sum of all the cost factors. For example, transmitter purchase, transmitter installation, transmitter maintenance, transmitter electricity, system operation, system improvement, outlet mall manager margin, and administrations were considered to be the cost factors in the business model. System development cost was not included here since it was considered to be an initial investment. The calculation was shown in Eq. (9.3).

$$Annual\ Cost_{i,j} = \sum \left(PC_{i,j} + IC_{i,j} + MC_{i,j} + EC_{i.j} + SO_{i,j} + SI_{i,j} + MB_{i,j} + AC_{i,j} \right)$$

Eq. (9.3)

PC: Transmitter Purchase Cost

IC: Transmitter Installation Cost

MC: Transmitter Maintenance Cost

EC: Transmitter Electricity Cost

SO: System Operation Cost

SI: System Improvement Cost

MB: Margin to Building Manager

AC: Administration Cost

Finally, annual Free Cash Flow (FCF) and Net Present Value (NPV) were calculated based on Eq. (9.4) and Eq. (9.5) respectively. System development cost was considered to be the initial investment in the NPV calculation and thus not included in the annual cash flow modeling. Working capital is also excluded for simplification of the model.

$$Annual\ FCF_{i,j} = \left(Annual\ Revenue_{i,j} - Annual\ Cost_{i,j} \right) \times (1 - T) + D_{i,j}$$

Eq. (9.4)

$$NPV_j = \sum_{i=1}^{t} \frac{Annual\ FCF_{i,j}}{(1+r)^i} - I_o$$

Eq. (9.5)

T: Tax Rate

D: Depreciation

r: Discount Rate

t: Project Duration

I: Investment

I set the values for the Constraints and the Best Guess as shown in Table 9.3 and the values for the Assumptions in Table 9.4 for conducting the simulation.

Table 9.3 Constraint and Best Guess

Parameter	Value
Number of Tenant Shops	208
Number of IMES Transmitter	744
Project Duration	10 years
Tax Rate	40%
Depreciation (Uniform)	10 years
Administration Cost (% to Operation Cost)	10%

Table 9.4 Assumptions

Parameter	Min.	Likeliest	Max.
IMES Service Adoption Rate	50%	70%	90%
Transmitter Unite Price	$20	$100	$500
Transmitter Installation Cost	$25	$50	$75
Transmitter Maintenance Cost	$10	$20	$30
Transmitter Electricity Cost	$0.1	$0.2	$0.3
System Operation Cost	$10,000	$20,000	$30,000
System Improvement Cost	$5,000	$10,000	$15,000
Discount Rate	7%	10%	15%

9.5. Results and Discussions

9.5.1. Cash outflow evaluation

Table 9.5 shows 9 different scenarios for the cash out-flow. I assume that System Development Cost has 3 options ($50,000, $100,000 and $150,000) and it must be paid initially. Margin to Building Manager also has 3 options ($0, $10, $20) and to be paid annually per IMES transmitter.

Table 9.5 Cash Outflow Scenario

		System Development Cost		
		$50,000	$100,000	$150,000
Margin	$0	Scenario 1	Scenario 2	Scenario 3
	$10	Scenario 4	Scenario 5	Scenario 6
	$20	Scenario 7	Scenario 8	Scenario 9

First of all, the results of the NPV analysis are visually summarized in Fig. 9.4. It illustrated that when the initial investment for System Development Cost was as less as $50,000, all scenarios (Scenario 1, Scenario 4 and Scenario 7) showed positive NPV and also reached NPV breakeven earlier than 5th year regardless of the amount of Margin to Building Manager. In this case, a company could acquire more flexibility of decision making on how much it should pay to the building manager.

When the initial investment for System Development Cost was $100,000, all scenarios (Scenario 2, Scenario 5 and Scenario 8) still showed positive NPV regardless of the Margin. However, Scenario 8 (pays $20 to Building Manager per IMES Transmitter per year) cannot reached NPV breakeven in middle of the project. Therefore, paying $20 to building manager was slightly a risky decision making for a company.

When the initial investment for System Development Cost reached as much as $150,000, all scenarios (Scenario 3, Scenario 6 and Scenario 9) still show positive NPV regardless of the amount of Margin to Building Manager. However, Scenario 6 (pays $10 margin) and Scenario 9 (pays $20 margin) cannot reached NPV breakeven in middle of the project. In this case, a company was likely to be required to negotiate with building manager for exemption of the margin payment so as to design a feasible business model.

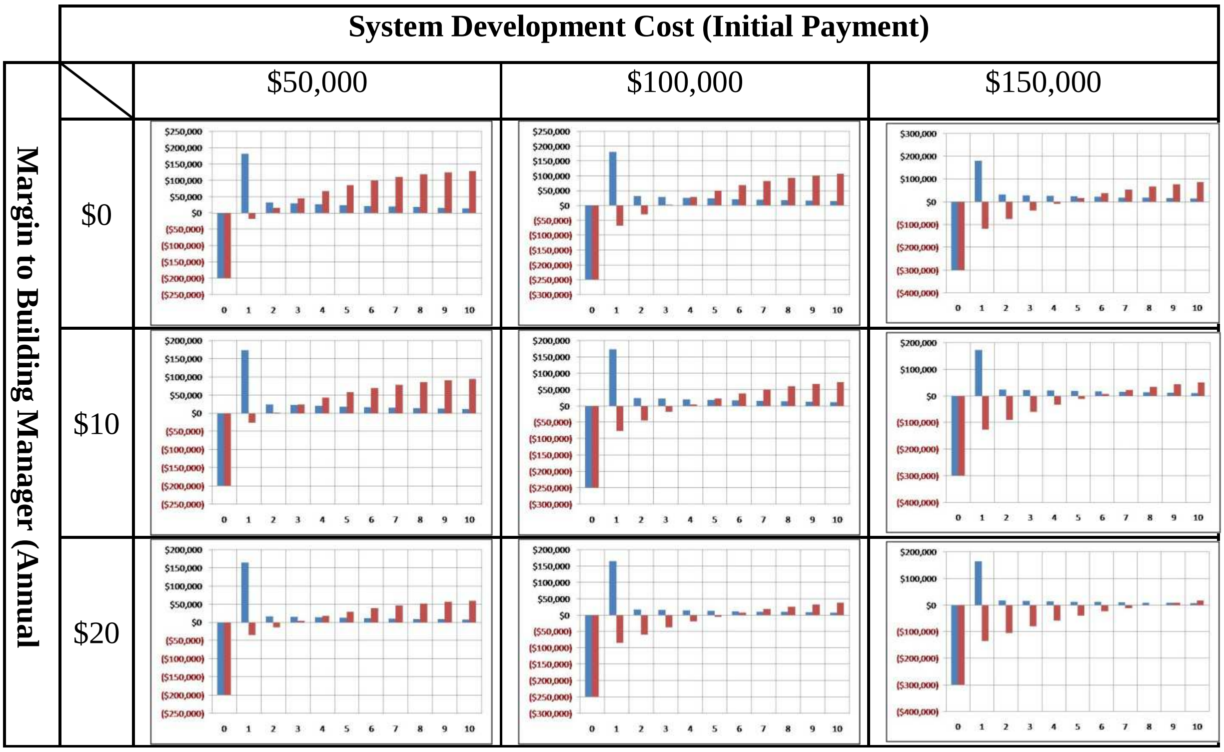


Fig. 9.4 NPV Analysis (Cash Outflow Scenario)
(Blue: Annual NPV, Red: Accumulated NPV)

Furthermore, I implemented Monte Carlo Simulation for each scenario (Fig. 9.5). In three scenarios, say, Scenario 6, Scenario 8 and Scenario 9, the certainty for acquiring positive NPV were less than 60%. In order words, if a company would like to keep the risk of negative NPV from the IMES business as less than 40%, then these options were not acceptable from the beginning. More concretely speaking, when a company invested $150,000 initially for System Development, then the only option for a company to take would be negotiation with the building manager for exemption of the margin. In the same way, when a company invested $100,000 initially, then the options to take would be either paying $10 for the margin or paying nothing to building manager.

In this way, it is possible to make decision on how much margin a company should pay to building manager so as to make the IMES business commercially feasible according to the amount of initial investment. Uncertainty of business system can be evaluated and designed based on the proposed approach.

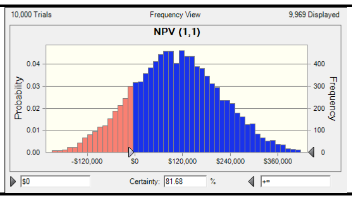
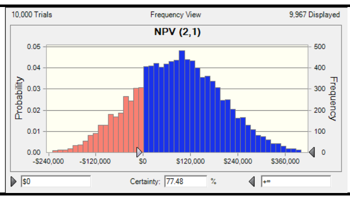
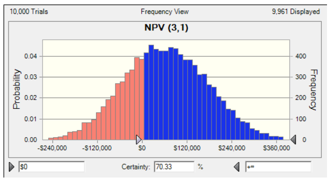
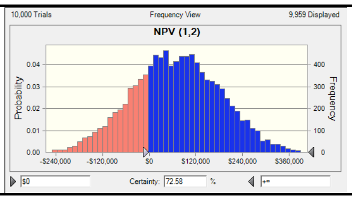
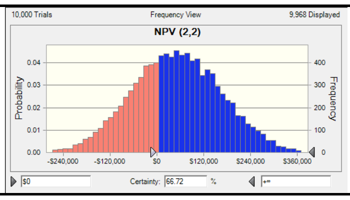
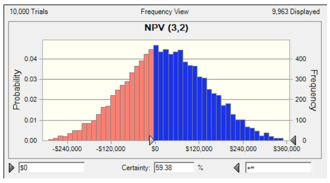
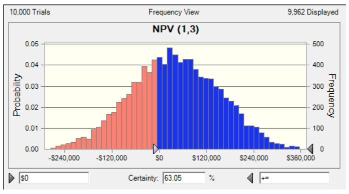
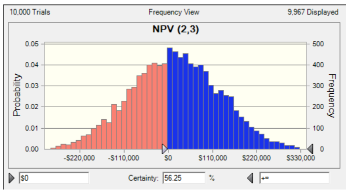
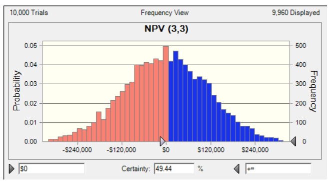
		System Development Cost (Initial Payment)		
Margin to Building (Annual Payment)		$50,000	$100,000	$150,000
	$0			
		NPV Positive: 81.68%	NPV Positive: 77.48%	NPV Positive: 70.33%
	$10			
		NPV Positive: 72.58%	NPV Positive: 66.72%	NPV Positive: 59.83%
	$20			
		NPV Positive: 63.05%	NPV Positive: 56.25%	NPV Positive: 49.44%

Fig. 9.5 NPV Distributions (Cash Outflow Scenario)
(Blue: Positive NPV, Red: Negative NPV)

9.5.2. Cash inflow evaluation

Table 9.6 shows 9 different scenarios for cash in-flow analysis. I assume that IMES Utility Fee would have two different schemes for payment from tenant shops in the mall; 1) Initial Payment and 2) Annual Payment. I designed 3 options for each payment scheme. As for the Initial Payment, 3 options are $0, $1,000 and $2,000 per shop. As for the Annual Payment scheme, 3 options are $500, $1,000 and $1,500 per year per shop.

Table 9.6 Cash Outflow Scenario

		IMES Utility Fee (Initial Payment)		
		$0	$1,000	$2,000
IMES Utility Fee (Annual Payment)	S500	Scenario 10	Scenario 11	Scenario 12
	$1,000	Scenario 13	Scenario 14	Scenario 15
	$1,500	Scenario 16	Scenario 17	Scenario 18

First of all, the results of the NPV analysis are visually summarized in Fig. 9.6. Contrary to the Cash Outflow analysis, there were greater distinctions among the scenarios in the Cash Inflow analysis. It visually showed that the IMES business was less likely to be feasible when a company set the annual payment as $500 regardless of the amount of the initial payment. In fact, Monte Carlo Simulation (Fig. 9.7) also showed that positive NPV was hardly achieved in Scenario 1 through Scenario 3. However, the situation dramatically improved when a company would double the annual payment for the IMES Utility Fee up to $1,000. Fig. 9.6 illustrated that positive NPV was kept even without requiring any initial payment for utilizing the IMES (Scenario 13) and the certainty for positive NPV marked more than 60% for both Scenario 14 ($1,000 for initial payment) and Scenario 15 ($2,000 for initial payment). Furthermore, when a company would triple the annual payment for the IMES Utility Fee up to $1,500, the situation further improved. As illustrated in Fig. 9.7, Scenario 16 through Scenario 18 (requiring $1,500 for annual payment) resulted in almost 100% certainty for positive NPV. It meant that the business risk would extremely minimize when a company set the annual payment as much as $1,500 regardless of the amount of the initial payment.

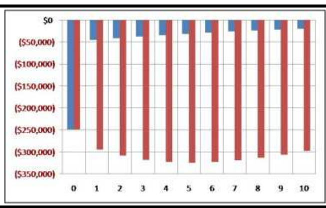
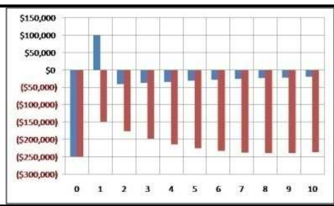
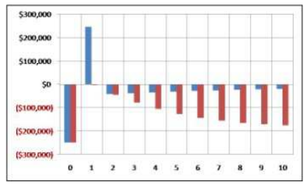
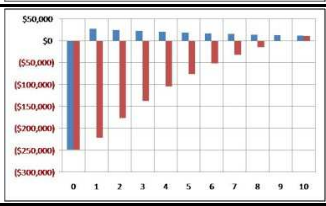
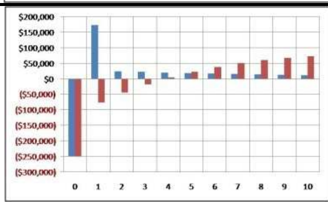
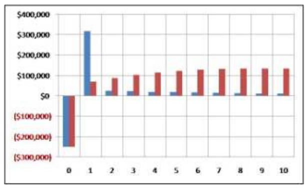
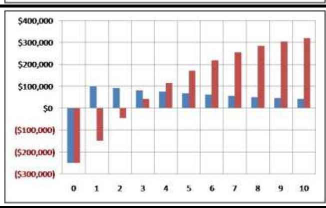
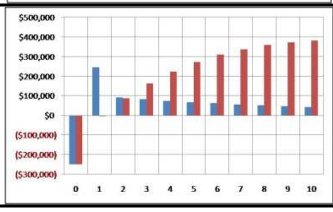
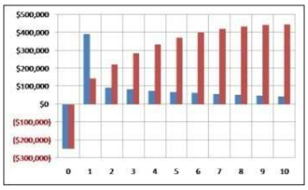
		IMES Utility Fee (Initial Payment)		
IMES Utility Fee (Annual Payment)		$0	$1,000	$2,000
	$500			
	$1,000			
	$1,500			

Fig. 9.6 NPV Analysis (Cash Inflow Scenario)
(Blue: Annual NPV, Red: Accumulated NPV)

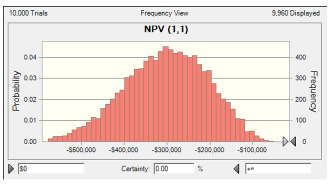
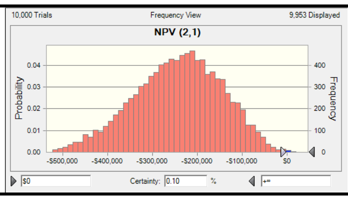
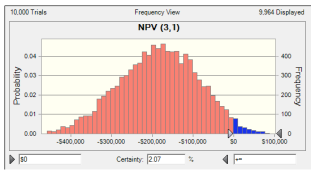
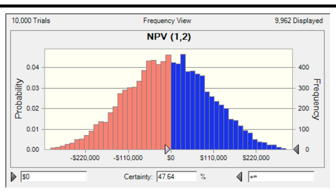
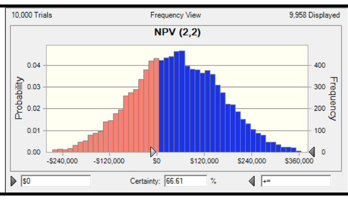
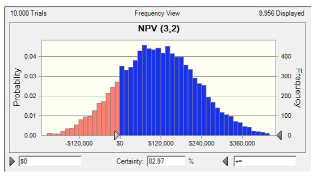
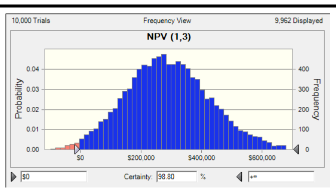
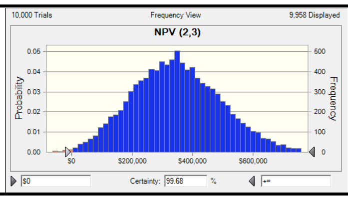
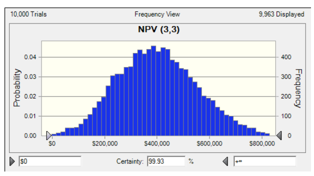
		IMES Utility Fee (Initial Payment)		
IMES Utility Fee (Annual Payment)		$0	$1,000	$2,000
	$500			
		NPV Positive: 0.00%	NPV Positive: 0.10%	NPV Positive: 2.07%
	$1,000			
		NPV Positive: 47.64%	NPV Positive: 66.61%	NPV Positive: 82.97%
	$1,500			
		NPV Positive: 98.80%	NPV Positive: 99.68%	NPV Positive: 99.93%

Fig. 9.7 NPV Distributions (Cash Inflow Scenario)
(Blue: Positive NPV, Red: Negative NPV)

9.6. Chapter Conclusions

The chapter discussed how to analyze uncertainty of business systems in investing emerging technology. The proposed matrix-based approach made it possible to conduct scenario analysis of a new business more efficiently and effectively. As a result of Scenario Analysis and Monte Carlo Simulation, I could identify several key factors for designing scalable business systems for the IMES. First, regarding the cash outflow, a company should carefully design the amount of margin to building manager according to the initial investment. When the initial investment exceeded more than $150,000, then the exemption of the margin should be negotiated with building manager. Second, regarding the cash inflow, design of the annually payment scheme was more critical than that of the initial payment. Designing the annual payment as $1,500 would provide more freedom for a company to design the initial payment from the tenant shops for the IMES service. It greatly affected the IMES service adoption rate in the beginning and the revenue in the end. The proposed methodology can be applied to any type of businesses with uncertainty. I believe that it contribute to design scalability of business system, which in turn, prevent emerging technology from falling into 'valley of death'.

(Intentionally Blank)

(Intentionally Blank)

Chapter 10. Systems Evaluation on Business Integration

10.1. Chapter Introduction

I have so far discussed systems evaluation on competitiveness and uncertainty of business. They can provide insights on degree of competitiveness and robustness that are critically important to consider scalability of business systems. In this chapter, I finally discuss integration of those factors and business operation so that a business can be evaluated from multiple perspectives and to acquire sustainability in market overtime.

Fig. 10.1 shows the scope of the research in Chapter 10. I attempt to evaluate business system in terms of its feasibility, profitability and scalability. For such purpose, I attempt to integrate Business Model Canvas (BMC) and System Dynamics for realizing seamless evaluation from a business concept level to an operational business system level. I believed that sustainability of a business can be enhanced through this holistic evaluation approach shown in Fig. 10.1.

New business development is one of critical issues for Japanese companies. According to the survey of the Ministry of Economy, Trade and Industry (METI), conducted in March 2010 (n = 729), 71.9% of Japanese companies feel necessity for new business development but only 43.8% of them actually move to take actions (METI, 2010). The other survey of METI "frontier human resources workshop report" (n = 330) shows that 78.2% of Japanese companies that working on new business development are not satisfied (METI, 2012). Regarding the reasons, around 60% of the companies pointed out the lack in-house human resources to lead new business development and around 70% answered the insufficiency of training programs. That is, the status quo for new business development is important issue for Japanese companies, but it is difficult to implement mainly due to the lack of human resources and skills to lead the activities.

The proposed method can support design and evaluation processes of new business development. It enables rapid hypothesis testing on business feasibility, profitability and growth ability that is necessary in early stage of business design.

In the following, I first provide brief explanations on a method of Business Model Canvas (BMC) in the section 10.2. The section 10.3 shows the proposed method which integrates BMC and System Dynamics. The section 10.4 verifies that the proposed method can meet the requirements derived from the purpose of business design. The section 10.5 validates the method by evaluating its effectiveness on business practice. I implemented the validation process within a joint research project with a company developing new businesses. Finally, I conclude the discussions and point out future works in the section 10.6.

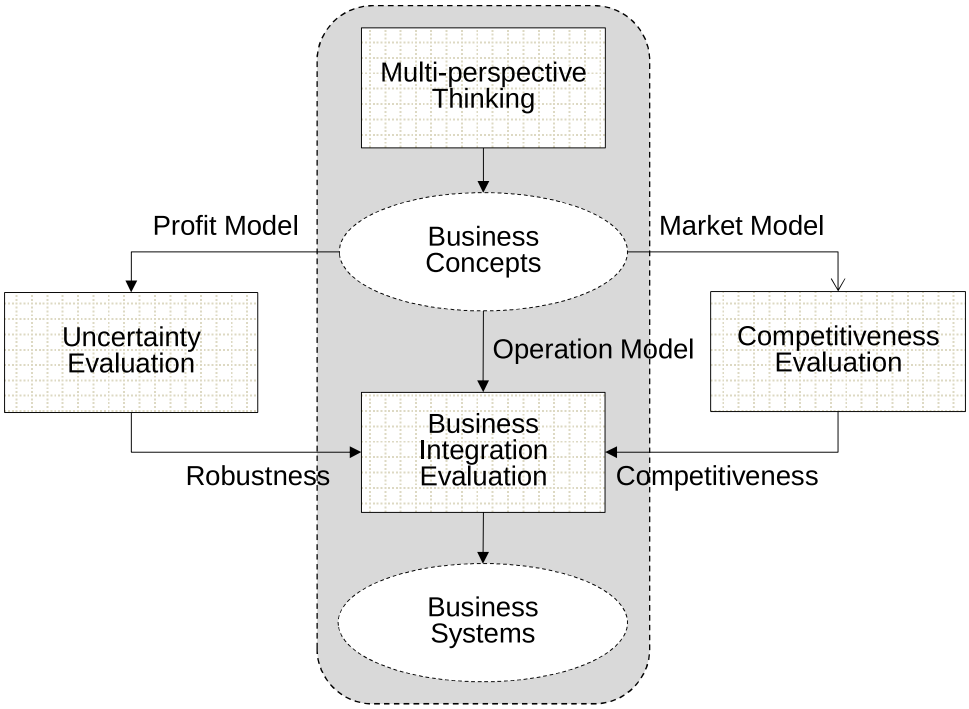


Fig. 10.1 Scope of Chapter 10 (Business Integration Evaluation)

10.2. Business Model Canvas (BMC)

Business Model Canvas (BMC) is a notation of a business developed by Osterwalder et al (Fig. 10.2). According to the definition, a business model is "rationale of how an organization creates, delivers, and captures values" (Osterwalder et al, 2010). So they attempted to propose a tool of visually describing the rationale of business relations (Fig. 10.2). BMC is used for decomposing a business into several elements and design each element individually and finally integrate them into a piece of canvas. More specifically, it divides a business into nine different building blocks: customer segments, value proposition, channels, customer relationships, revenue structure, key resources, key activities, key partners, and cost structure. The pre-defined format facilitates to design a business. The details of each block are summarized in Table 10.1.

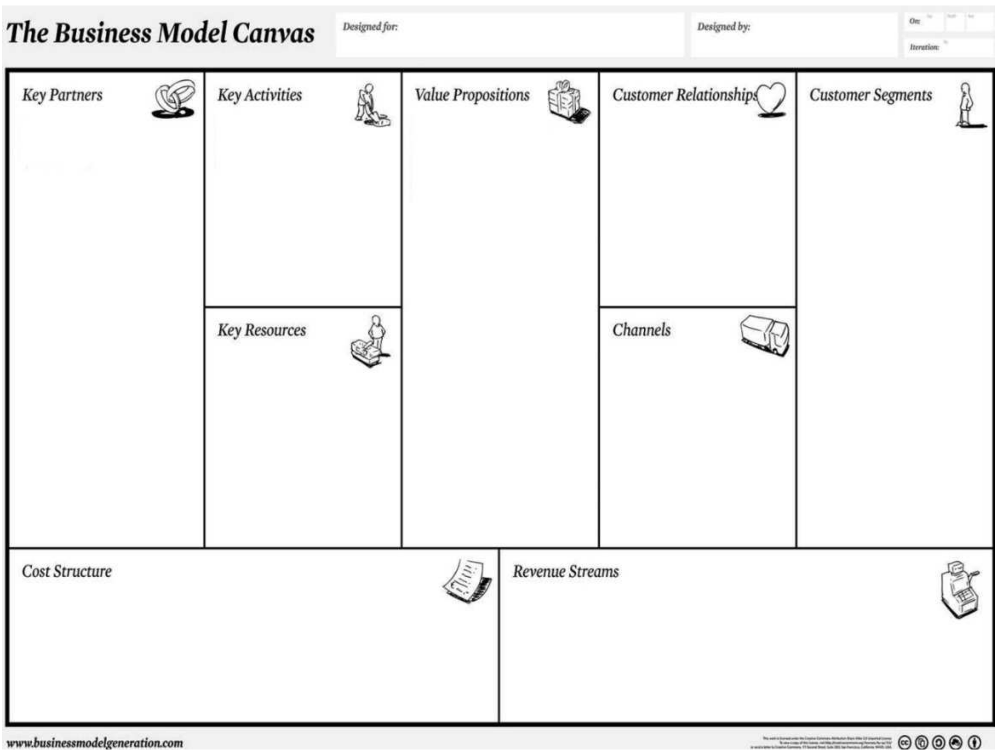


Fig. 10.2 Business Model Canvas (BMC)

The notion of decomposition and integration fits the fundamentals of systems engineering (SE). SE is “an interdisciplinary approach and means to enable the realization of successful system” (INCOSE SE Handbook, p.362, 2010) and often applied to design large-scale, complex systems such as space and aeronautics system. It considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs (INCOSE SE Handbook, p.362, 2010).

There is no formal order to design each building block when using BMC, but I think it is easier to begin either with value propositions or customer segments according to my experience. The first is product-out approach and the latter is market-in approach.

Table 10.1 Description of BMC (Osterwalder, 2010)

Name of Block	Descriptions	Examples
Customer Segments	Defines the different groups of people or organizations an enterprise aims to reach and serve	Mass market, Niche market, Segmented market, Diversified market, Multi-side platforms
Value Propositions	Describes the bundle of products and services that create value for a specific customer segment	Performance, Design, Brand, Price, Cost reduction, Risk reduction, Accessibility, Newness
Channels	Describes how a company communicates with and reaches its customer segments to deliver a value propositions	Sales force, Web sale, Own store, Partner store, Wholesale
Customer Relations	Describes the types of relationships a company establishes with specific customer segment	Personal assistance, Self-service, Automated service, Communities, Co-creation
Revenue Streams	Represents the cash a company generates form each customer segments (Cost must be subtracted	Asset sales, Usage fee, Subscription fees, Lending/Renting/Leasing, Licensing, Brokerage fees,

	from revenues to create earnings)	Advertising
Key Resources	Describes the most important assets required to make a business model work	Physical, Intellectual, Human, Financial
Key Activities	Describes the most important things a company must do to make its business model work	Production, Problem solving, Platform, Network
Partners	Describes the network of suppliers and partners that make the business model work	Optimization, Economy of Scale, Reduction of Risk and Uncertainty, Acquisition of particular resources and activities
Cost Structures	Describes all costs incurred to operate a business model	Fixed cost, Variable cost, Tax, Administration Cost, Labour cost

10.3. Methodology

10.3.1. Qualitative modelling of business systems

When describing a qualitative business model using BMC, the relationships among component are categorized by three different kinds of flows: product and service flow, cash flow and information flow (Fig.10.3). This is to facilitate integration of BMC with system dynamics. The same type of flow analysis for visualizing a business structure is proposed as Customer Value Chain Analysis (Ishii and Iino, 2008) but the advantage of the proposed method is its easiness and comprehensiveness due to the pre-defined components of business.

For instance, product and service flow moves from value propositions to customer segment through channels. Information flow exists from customer segments to key activity through customer relationship. This represents feedbacks from customers such as demands and preferences. The customer feedbacks are further sent to partners as information flow. Moreover, key activity and key resource are inevitable elements for providing values to customers, and here exists product and service flow. When a company is not able to perform key activities or secure key resources by itself, it needs suppliers as partners and product and service flow exists. Key activity, key resource and partners are all cost factors and therefore information flow exists to cost structure. Based on the cost information, cash outflow is generated. On the other hand, cash inflow is generated from customer segment to revenue streams. It represents sales from customers. The difference between cost and revenues is counted as profits.

I propose to analyse a business system in service and product flow, cash flow and information flow so that it can be efficiently transformed from a qualitative concept to quantitative stock and flow model using system dynamics later.

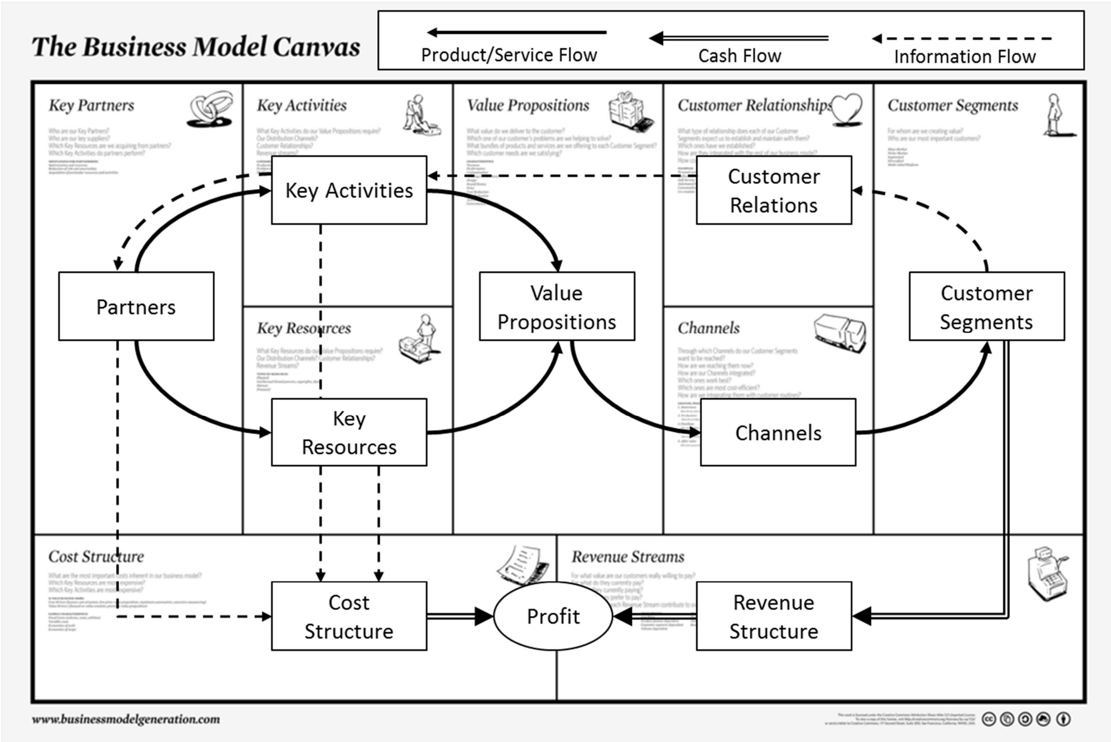


Fig. 10.3 Qualitative modelling with Business Model Canvas
(Created by the author based on Osterwalder et al.2010)

10.3.2. Quantification of business system elements

The next step is to convert qualitative information on BMC into qualitative variables for preparing a computer-aided simulation. I propose BMC-SD conversion matrix (Table 10.2) for the purpose of systematically facilitate the conversion process. Table 10.2 shows an example. The matrix includes four different variables: variable 1, variable 2, variable 3 and variable 4. The circle in the matrix means that the variable belongs to the building blocks on BMC and the variable must be defined for building SD model. The sign S represents Stock variable, F represents Flow variable, A represents Auxiliary variable and P represents Parameter. Unit is also defined in terms of character of the variable and the purpose of simulation.

In Table 10.2, there is a circle in a cell of Customer Segments and variable 1 followed by the sign of S. It means that variable 1 is a Stock variable and must be placed on Customer Segments building block on BMC. Number of customers is an example. In the same way, variable 2 belongs to Customer Relations. The variable is a Flow variable and must be placed on the building block. Order Rate and Order Fulfilment Rate are examples. Variable 3 belongs to Key Resources. Assets and human resources can be placed on the building block. Variable 4 belongs to Cost Structure. Unit Production Cost, Unit Material Cost, Unit Distribution Cost are major parameters to be placed in the building block.

The BMC-SD conversion matrix enables to identify essential variables in a business systematically and comprehensively. It facilitates SD modelling process for simulation. Furthermore, it contributes to collaborative works with multiple people dividing works such as information search according to each building block. Decomposition and integration of variables are further facilitated by the matrix structure which results in time reduction of business design process.

Table 10.2 BMC-SD conversion matrix

	S: Stock Variable F: Flow Variable A: Auxiliary Variable P: Parameter		BMC Blocks								
			Customer Segments	Value Propositions	Channels	Customer Relations	Revenue Stream	Key Resources	Key Activities	Key Partners	Cost Structure
Variable Name	Sign	Unit	CS	VP	CH	CR	R$	KR	KA	KP	R$
Variable 1	S		○								
Variable 2	F					○					
Variable 3	A							○			
Variable 4	P										○

10.3.3. *Quantitative modelling of business system*

After quantifying all variables in a business system using the BMC-SD conversion matrix, I started to build a simulation model on the BMC using system dynamic. AnyLogic 6.8.0 was used for the modeling. I assumed a start-up business of new product sales toward a new market in this research. Fig. 10.4 illustrates the model overview.

In BMC, there are nine different building blocks (Fig. 10.2, Table 10.1) but I build the system dynamics model with four different sub-models: 1) Market Model, 2) Supply Chain Model, 3) Human Resource Management (HRM) Model and 4) Finance Model (Fig. 10.4). The market model represents penetration of a new product to a market and includes variables such as market size, adoption rate, number of customers, sales prices. The supply chain model represents supply of materials, production and delivery of a new product. The human resource management model represents employment and lay off of labors that are necessary for production. The finance model represent sales and costs of a business and includes variables such as fixed cost, variable cost, administration cost, sales and profit rate. Each model structure and equation is explained more in detail below.

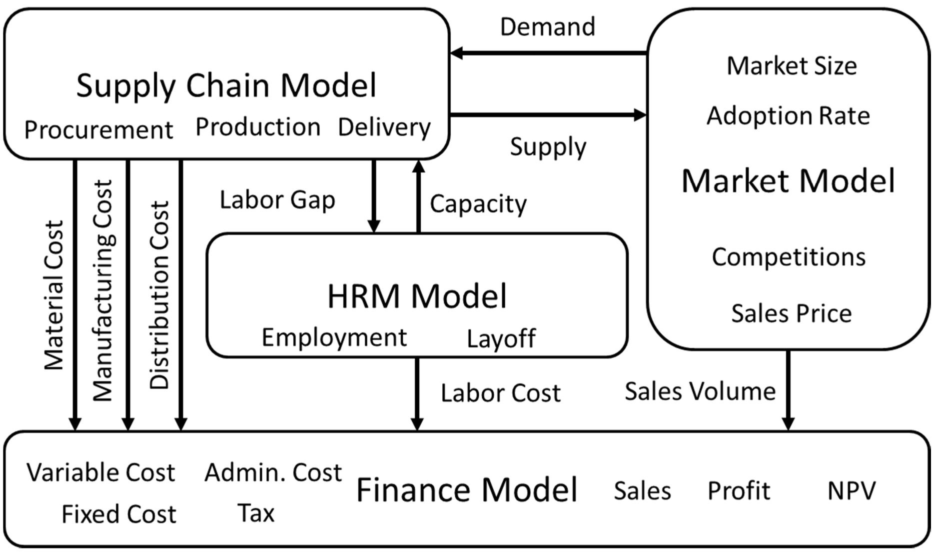


Fig. 10.4 Model overview

10.3.3.1. Market Model

I build the market model on the basis of Bass Diffusion model (Bass, 1969) and Sterman's repeated purchase model (Sterman, pp.342-344, 2000). Bass Diffusion Model is a classic approach to represent non-linear dynamics of business system growth overtime using logistic equation. It enables to consider both internal growth factor and external growth factor. Sterman's model is an improvement of the Bass Diffusion Model which enables to consider not only the first purchase but also continuous purchases of new product overtime.

Adoption of a new product (Adoption) is calculated by the sum of Adoption by Ad and Adoption by Word of Mouth (Eq.10.1). Adoption by Ad is the product of Potential Customer and Ad Effectiveness (Eq. 10.2). Adoption by Word of Mouth is calculated by the product of Potential Customer, Contact Rate, Product Attractiveness and Customers divided by Market Size (Eq. 10.3). Division of Customers by Market Size means the probability of encountering a new product adopter when someone meets someone in a market. Contact Rate represents how frequently a person meets someone in a market. Product Attractiveness controls the probability of adopting a new product at each new encounter in a market.

$$\text{Adoption} = \text{Adoption by Ad} + \text{Adoption by Word of Mouth}$$

(Eq. 10.1)

$$\text{Adoption by Ad} = \text{Potential Customer } \times \text{Ad Effectiveness}$$

(Eq. 10.2)

$$\begin{aligned}\text{Adoption by Word of Mouth} \\ &= \text{Potential Customer} \times \text{Contact Rate} \times \text{Product Attractiveness} \\ &\times \frac{\text{Customers}}{\text{Market Size}}\end{aligned}$$

(Eq. 10.3)

Customer Order is calculated by the sum of Initial Purchase and Repeated Purchase (Eq. 10.4). Initial Purchase is the product of Initial Sales per Customer and Adoption (Eq. 10.5). Repeated Purchase is the product of Average Consumption per Customer and Customers (Eq. 10.6). I also includes discard of a product which is calculated by the product of Discard Rate and Customer (Eq. 10.7). It means that some customer dislike the product and stop using it. I assumed that Sales Price is fixed throughout the simulation.

$$\text{Customer Order} = \text{Initial Purchase} + \text{Repeated Purchase}$$

(Eq. 10.4)

$$\text{Initial Purchase} = \text{Initial Sales per Customer } \times \text{Adoption}$$

(Eq. 10.5)

$$\text{Repeated Purchase} = \text{Average Consumption per Customer } \times \text{Customers}$$

(Eq. 10.6)

$$\text{Discard} = \text{Discard Rate } \times \text{Customers}$$

(Eq. 10.7)

10.3.3.2. Supply Chain Model

The supply chain model assumes a simple pipeline model developed by stock and flow connections. It provides the finance model with Shipment Rate, Production Rate and Supply Rate. Shipment Rate is calculated by Desired Shipment Rate which is the division of Backlog (Eq. 10.8) and Delivery Time (Eq. 10.9). Revenue is counted at the time of shipment. Production Rate is calculated considering production time delay (Eq. 10.10). Inventory is calculated by the integral of Production Rate minus Shipment Rate (Eq. 10.11) and Material is calculated by the integral of Supply Rate minus Production Rate (Eq. 10.12).

$$\text{Backlog} = \int (\text{Order Rate} - \text{Order Fullfillment Rate})$$

(Eq. 10.8)

$$\text{Shipment Rate} = \text{Desired Shipment Rate} = \frac{\text{Backlog}}{\text{Delivery Time}}$$

(Eq. 10.9)

$$\text{Production Rate} = \text{Delay (Customer Order Rate, Production Time)}$$

(Eq. 10.10)

$$\text{Inventory} = \int (\text{Production Rate} - \text{Shipment Rate}) + \text{Initial Inventory}$$

(Eq. 10.11)

$$\text{Material} = \int (\text{Supply Rate} - \text{Production Rate}) + \text{Initial Material}$$

(Eq. 10.12)

10.3.3.3. Human Resource Management Model

In the human resource management model, Required Employee is calculated by the division of Production Rate by Production per Employee (Eq. 10.13). When there is discrepancy between the two, Labor Gap is calculated by the subtraction of Employee from Required Employee (Eq. 10.14). It represents gradual growth of a start-up company. Employment Rate is the division of Labor Gap by Labor Adjustment Rate (Eq. 10.15).

Labor Cost is calculated by the product of Number of Employee and Unit Labor Cost (Eq. 10.16). It becomes an input to the finance model.

$$\text{Required Employee} = \frac{\text{Production Rate}}{\text{Production per Employee}}$$

(Eq. 10.13)

$$\text{Labor Gap} = \text{Required Employee} - \text{Employee}$$

(Eq. 10.14)

$$\text{Employment Rate} = \frac{\text{Labor Gap}}{\text{Labor Adjustment Time}}$$

(Eq. 10.15)

$$\text{Labor Cost} = \text{Number of Employee} \times \text{Unit Labor Cost}$$

(Eq. 10.16)

10.3.3.4. Finance Model

Finance model is composed of cost structure and revenue structure. Assume invoice to be sent on the basis of the delivery information from the SCM model (Shipment Rate), while taking into consideration of uncollectible rate (Default Rate). Revenue is calculated by the product of these variables and Sales Price (Eq. 10.17).

$$\text{Revenue} = \text{Sales Price} \times \text{Shipment Rate} \times \text{Default Rate}$$

(Eq. 10.17)

Total Cost is the sum of Operation Cost and Admin Cost (Eq. 10.18). Admin Cost is calculated by the product of Operation Cost and Admin Cost Rate (Eq. 10.19). Operation Cost is the sum of Variable Cost and Fixed Cost (Eq. 10.20). Variable Cost is the sum of Material Cost, Production Cost and Distribution Cost (Eq. 10.21). Material Cost is the product of Unit Material Cost and Supply Rate (Eq. 10.22). Production Cost is the product of Unit Production Cost and Production Rate (Eq. 10.23). Distribution Cost is the product of Unit Distribution Cost and Shipment Rate (Eq. 10.24). Fixed Cost is calculated by the sum of Labor Cost and Rent (Eq. 10.25). Labor Cost is the product of Number of Employees and Unit Labor Cost (Eq. 10.26).

$$\text{Total Cost} = \text{Operation Cost} + \text{Admin Cost} \tag{Eq. 10.18}$$

$$\text{Admin Cost} = \text{Operation Cost} \times \text{Admin Cost Rate} \tag{Eq. 10.19}$$

$$\text{Operation Cost} = \text{Variable Cost} + \text{Fixed Cost} \tag{Eq. 10.20}$$

$$\text{Variable Cost} = \text{Material Cost} + \text{Production Cost} + \text{Distribution Cost} \tag{Eq. 10.21}$$

$$\text{Material Cost} = \text{Unit Material Cost} \times \text{Supply Rate} \tag{Eq. 10.22}$$

$$\text{Production Cost} = \text{Unit Production Cost} \times \text{Production Rate} \tag{Eq. 10.23}$$

$$\text{Distribution Cost} = \text{Unit Distribution Cost} \times \text{Shipment Rate} \tag{Eq. 10.24}$$

$$\text{Fixed Cost} = \text{Labor Cost} + \text{Rent}$$

(Eq. 10.25)

$$\text{Labor Cost} = \text{NUmber of Employees} \times \text{Unit Labor Cost}$$

(Eq. 10.26)

The model includes a concept of free cash flow for evaluating a business system with actual transactions of money among players. All cash enter the stock of free cash flow with a certain time delay. It represents time discrepancy between the purchase and the actual payment by customers. Depreciation of assets is also considered to be cash inflow and is added to the same stock. On the other hand, cash outflow is calculated with the sum of total cost and investment and deducted from the stock. I assumed that a company would invest a certain part of its revenue to improve and expand the business.

10.4. Verification

I verify the proposed method examining whether it can meet the requirements for the purpose. Since it is used for designing and evaluating business system seamlessly, two requirements can be introduced. The first requirement is reproducibility of the method. A business concept must be transformed into a simulatable SD model on a piece of canvas. So I examine if I can convert a visualized business concept into a SD model on BMC. The second requirement is functionality of the method. Three fundamental factors must be evaluated in terms of business system: feasibility, profitability and growth ability. Therefore, I examine if I can evaluate the three factors using the proposed method.

10.4.1. Verification on reproducibility

In this verification, I assumed a start-up business of new product sales toward a new market and examined the model building process. Fig. 10.5 shows the result of SD model building on BMC. Using BMC-SD conversion matrix (Appendix 3), I could successfully transform a concept level of business idea into several variables in business system and then built a simulatable SD model on the same BMC. It clearly shows the reproducibility of the method for the purpose of designing and evaluating business system seamlessly. The SD modelling process requires some knowledge on system dynamics but we can prepare several pre-defined models in advance which are typical in business practice. It means that the method enable us to evaluate business system quickly only by setting some value of the parameters. I think that the method greatly contributes rapid hypothesis testing in business system evaluation and the first requirement is verified.

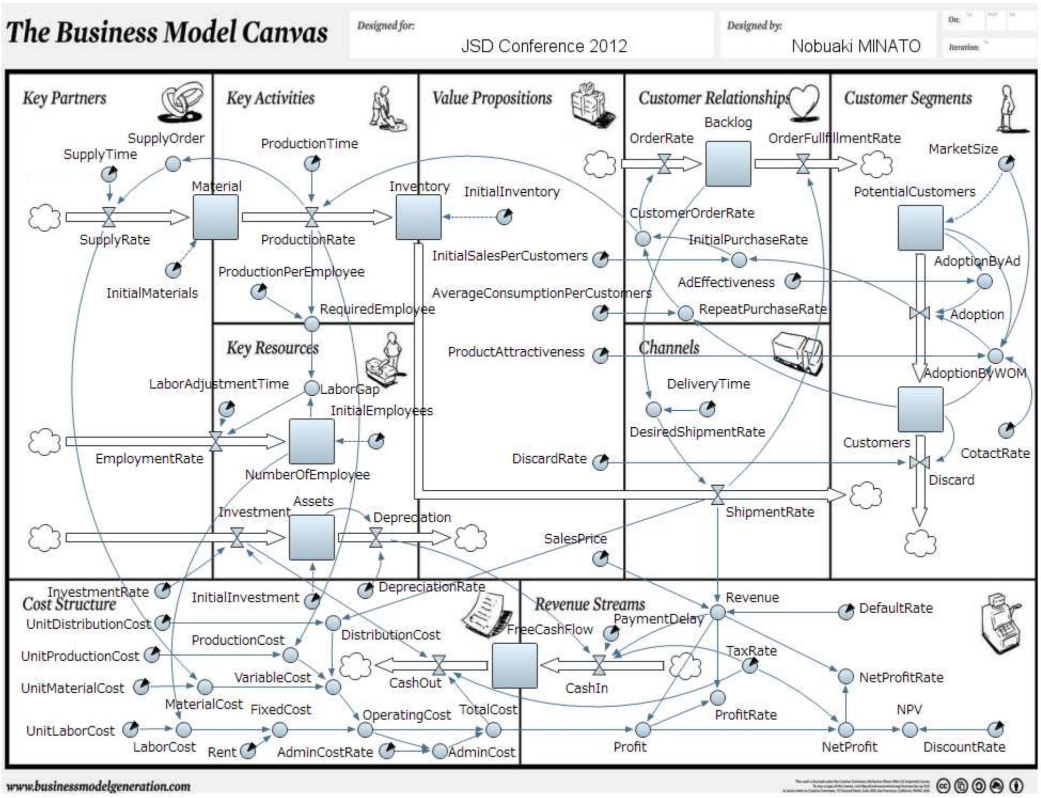


Fig. 10.5 SD model on BMC

10.4.2. Verification on functionality

The next verification is examination of functionality of the method. I verify by running a simulation of the same start-up business for 10 years. The assumptions in the simulation are summarized in Table 10.3 (Baseline).

10.4.2.1. Evaluation on feasibility of business

I first examine whether it is possible to evaluate feasibility of a business. In this examination, feasibility means that there is no malfunction in business operation under the conditions set for the simulation. More specifically, no major deviation occurs between the variables that are critical for business operation such as customer order, product delivery, production and raw material supply. Fig. 10.6 shows the simulation results regarding Order, Shipment, Production and Supply under the baseline scenario. It shows that there is no huge discrepancy between the variables. It means that the business operations are well-balanced and thus we can expect the business is likely to be feasible. The ideal results were caused by the proportional setting of the initial parameters in the baseline simulation. I consistently set the time delay as 1 month for every process of shipment, production, supply. If I set those parameters disproportionately, then the unbalance of business operation would occur and business feasibility could not be expected. For example, if I set the supply delay as 2 month and the production delay as 3 months, the result becomes as Fig. 10.7. Since deviation occurs between the variables, a more careful management is required.

Fig. 10.8 shows the state of Backlog, Inventory and Material in the business simulation. It illustrates the backlog rapidly increases from the beginning and dissolves around the end of the second year. Backlog sometimes brings about customer loosing so the lead time reduction should be reconsidered. Regarding the inventory, it is stable throughout the simulation period. It implies possibility of cost reduction by compressing the inventory level. The model can be used for inventory management. Regarding the material, on the other hand, it is fluctuating and there is undersupply in the second year. The undersupply implies the stop of operation in a production line so I changed the initial value setting of the material from 200 to 300 and rerun the simulation (Fig. 10.9). The result shows that the undersupply can be resolved but the material continuously increases to the level of the initial state in the latter stage of the simulation. It is mainly due to the saturation of the market which brings about slowdown of customer order overtime.

Furthermore, when considering time delay in supply (2 month) and time delay in production (3 month) on the same parameter settings, both the material and the inventory face undersupply (Fig. 10.10). It implies the stop of operation in a production line so I changed the initial value setting as 500 for the both and rerun the simulation (Fig. 10.11). The result shows that the undersupply can be resolved throughout the simulation but both the material and the inventory return to increase to the level of the initial state. It implies the necessity for optimal supply chain management from the beginning. The method enables to simulate different business scenario easily and quickly so it can contribute to enhance feasibility evaluation of business system.

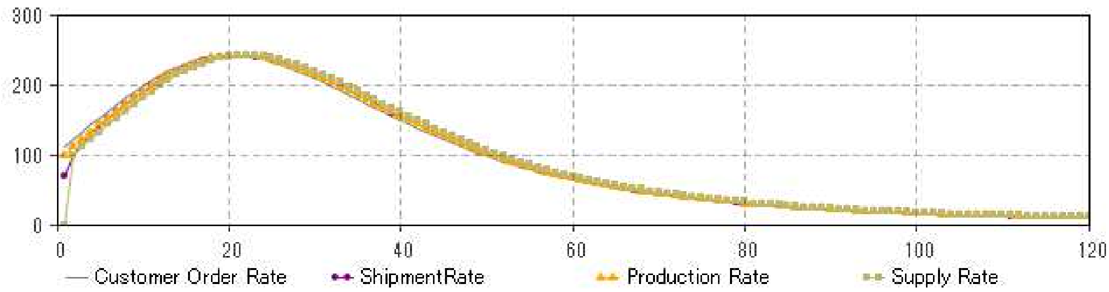


Fig. 10.6 Order, Delivery, Production, Supply (Baseline)

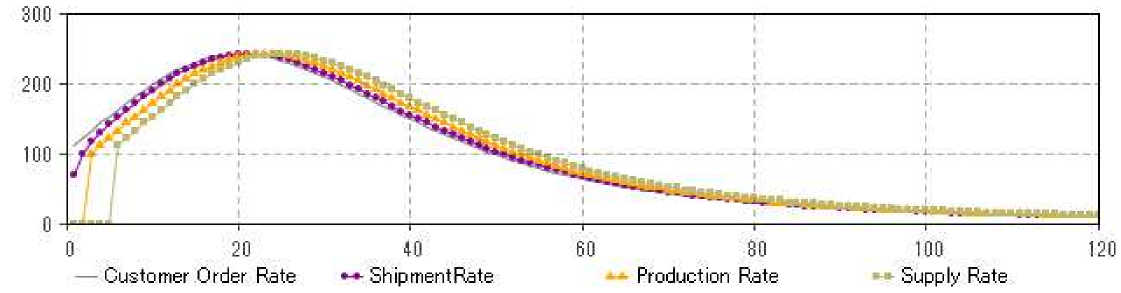


Fig. 10.7 Order, Delivery, Production, Supply (Supply Time=2, Production Time=3)

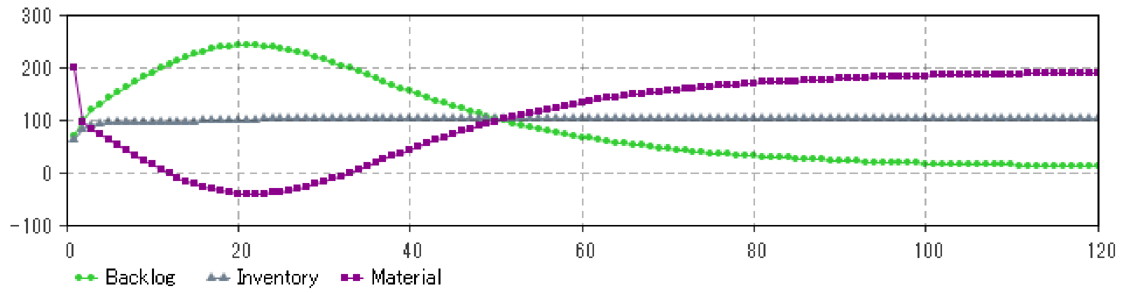


Fig. 10.8 Backlog, Inventory, Material (Baseline)

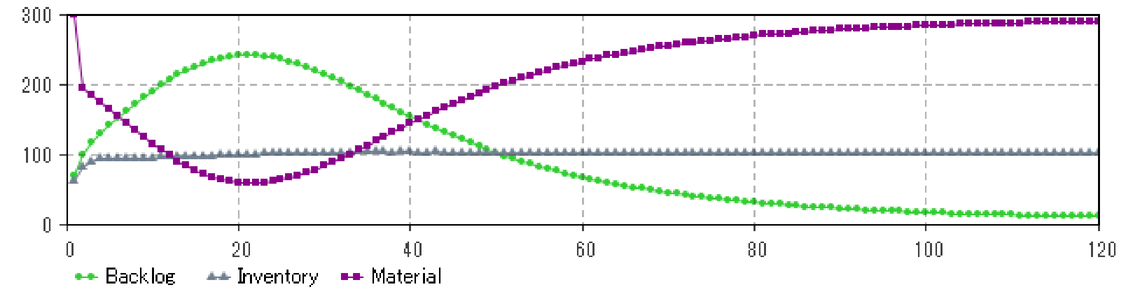


Fig. 10.9 Backlog, Inventory, Material (Initial Material=300)

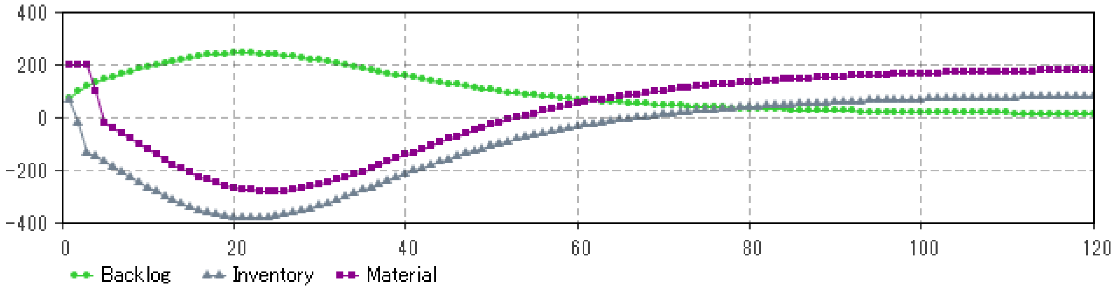


Fig. 10.10 Backlog, Inventory, Material (Supply Time=2, Production Time=3)

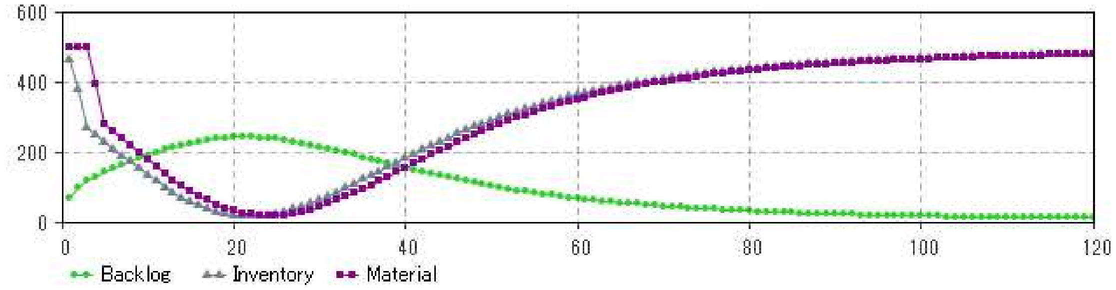


Fig. 10.11 Backlog, Inventory, Material (Initial Inventory=500, Initial Material=500)

10.4.3. Evaluation on profitability of business

Secondly, I examine whether it is possible to evaluate profitability of a business. With the proposed method, revenues, costs, profits, net present values, profit rate, net profit rate and cash flow in a business can be considered in the simulation.

Fig. 10.12 shows the results of revenue, total cost and profit and Fig. 10.13 shows profit rate and net profit rate under the baseline setting. It illustrates that the revenue gradually increases but the total cost exceeds the revenue overtime (Fig. 10.12). The profit rate gradually aggravates and reaches negative value in the end (Fig. 10.13). It implies unprofitability of a business so I changed the initial value setting of sales price from 1500 to 2000 and rerun the simulation (Fig. 10.14). The result shows that the revenue exceeds the total cost and the profit rate can be maintained as positive values except for the last stage of the simulation. We cannot change the macroscopic behaviour of the profitability in this business caused but we can manage the profitability by influencing some critical parameter such as prices. Thus, profitability of business can be evaluated with the proposed method.

In addition to accounting-based analysis such as revenue and profit, the method enables cash flow-based analysis as well. Free cash flow is a term in finance describing a state of cash in hand in a business or in a company. It is usually calculated by subtracting cash out from cash in. The advantage of considering free cash flow is that it can prevent business insolvency due to liquidity problems always paying attention to cash in hand. Positive free cash flow means that a business is managed stably. Negative free cash flow means that a business might be in danger of bankruptcy. Fig. 10.16 shows the result of cash in and cash out under the baseline setting. It illustrates that the cash in exceeds cash out throughout the simulation period and thus the free cash flow is also continuously positive and increases overtime (Fig. 10.17). It implies that there is low risk of black-ink bankruptcy in this business.

However, when I include 6 months of customer payment delay in the simulation, the cash in is relatively delayed to the cash out (Fig. 10.18). Fig. 10.19 shows the result of free cash flow considering the payment delay. It clearly shows that there is a certain period of time when free cash flow is stayed negative. It means the business is likely to be bankrupted unless it has some finance measure outside the company. In this case, the behaviour of revenue is the same as that of baseline setting since accounting based analysis does not consider payment delay. Time delay often occurs in reality and it critically affects sustainability of business. A start up business is generally associated with high uncertainty and its bankruptcy risk is high. The proposed method can evaluate not only profitability of a business but also risk of bankruptcy so that a company can prepare some countermeasure beforehand by knowing when cash shortage occurs.

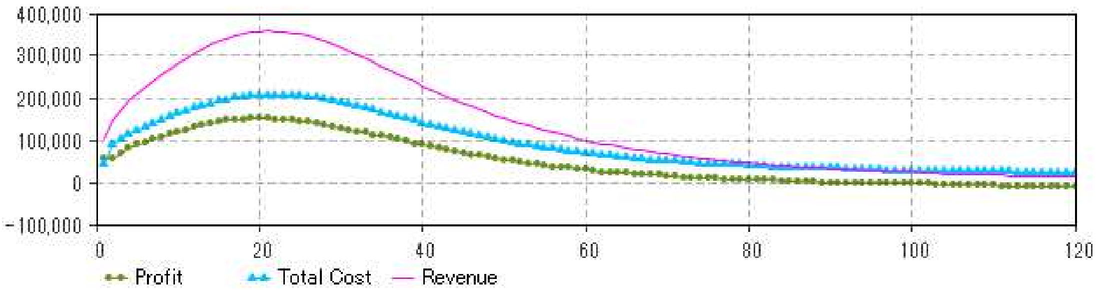


Fig. 10.12 Sales, Total Costs, Profits (Baseline)

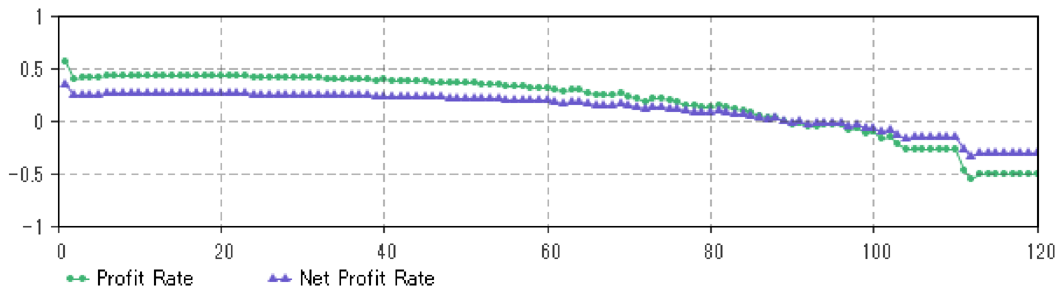


Fig. 10.13 Profit Rate and Net Profit Rate (Baseline)

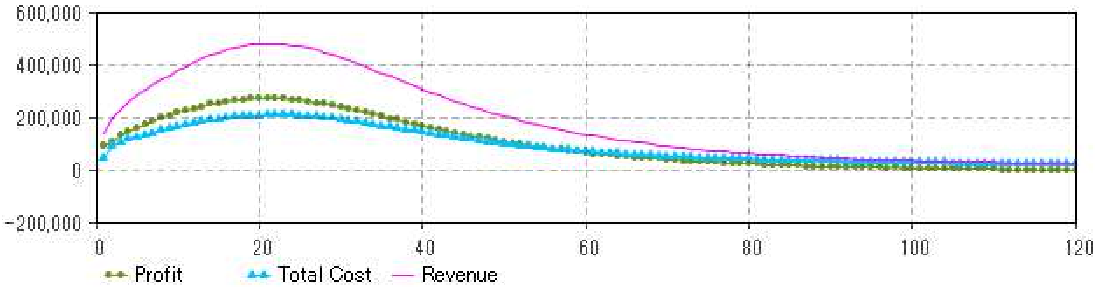


Fig. 10.14 Sales, Total Costs, Profits (Sales Price=2000)

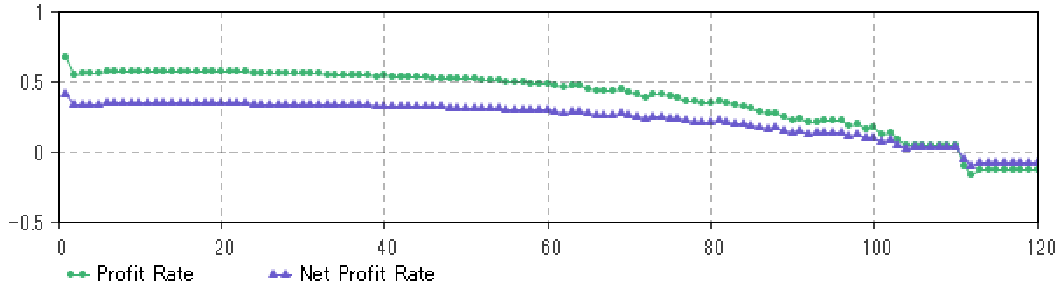


Fig. 10.15 Profit Rate and Net Profit Rate (Sales Price=2000)

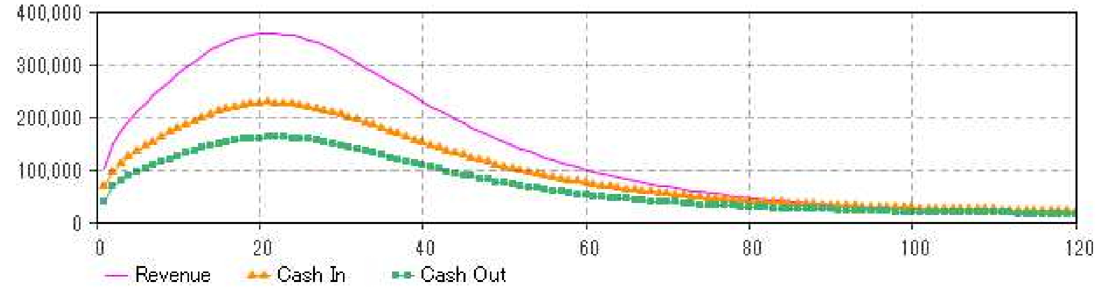


Fig. 10.16 Cash in and Cash out (Baseline)

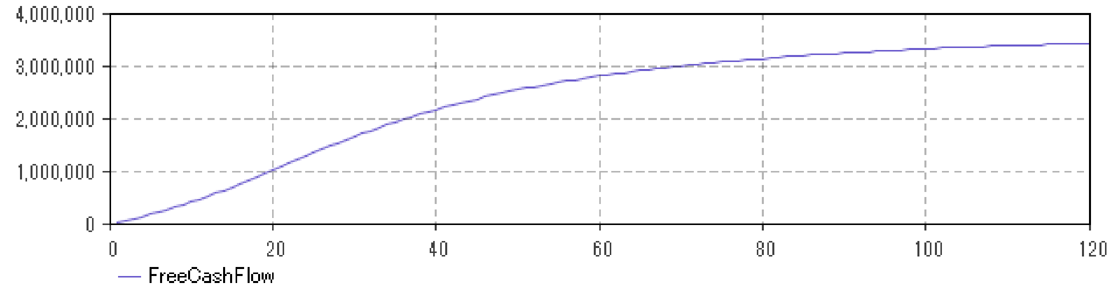


Fig. 10.17 Free Cash Flow (Baseline)

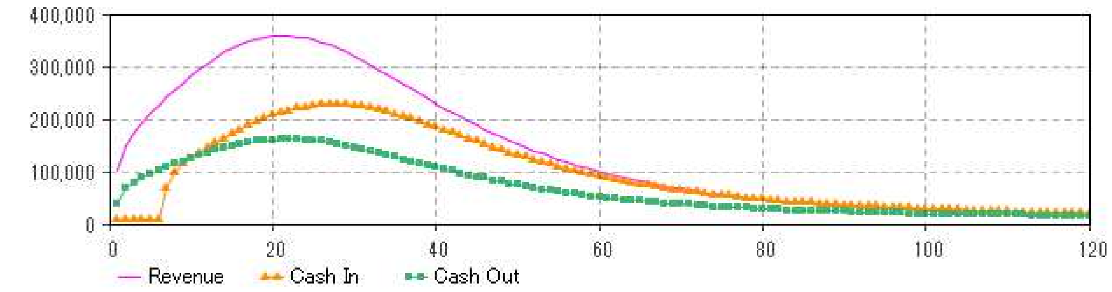


Fig. 10.18 Cash in and Cash out (Payment Delay=6)

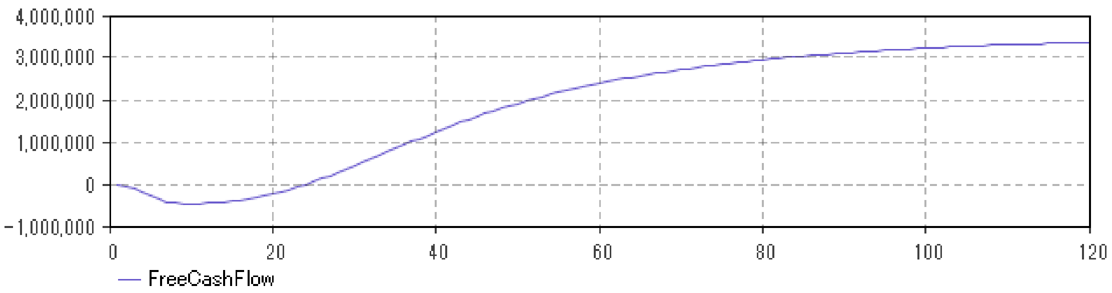


Fig. 10.19 Free Cash Flow (Payment Delay=6)

10.4.4. Evaluation on growth ability of business

Finally, I examine whether it is possible to evaluate growth ability of a business. Fig. 10.20 shows the result of market penetration of the new product to the new market. At the baseline setting, it acquires around 60% of the market share in 5 years and then gradually loses it until the end of the simulation. This is mainly due to the consideration of obsolescence of the product in the simulation model. But we can maintain or even increase the market share by effectively managing advertisement and word of mouth on the product.

To evaluate such management, I changed the initial value setting of AdEffectiveness from 0.01 to 0.03 and rerun the simulation. Fig. 10.21 shows the result. It represents a strategy of investing on advertisement and promotes product adoption. It illustrates 100% penetration of the market in the end. Advertisement is one of the measures to enhance the market share but it requires a certain amount of expenditure and it might influence profitability of business. The proposed method can evaluate such systemic issue as well.

Another management strategy is to enhance product attractiveness which in turn influences the product adoption by word of mouth. I changed the initial value setting of Product Attractiveness from 0.05 to 0.1 and rerun the simulation. Fig. 10.22 shows the result. As in the case of Fig. 10.21, the market penetration rate drastically improved and it finally reached 100% (Fig. 10.22). But increase of product attractiveness usually requires R&D investment or price reduction so this strategy also has systemic issue of influencing profitability of business.

Finally, I set AdEffectiveness as 0.02 and Product Attractiveness as 0.06 and rerun the simulation. Fig. 10.23 shows the result. In this case, the market penetration rate rapidly increases in the beginning and is stably maintained around 80%. It implies that appropriate combination of value setting for these two parameters makes it possible to control the demand level for proportioned production and supply. It is likely to contribute stable growth of a business with well-planned investment for production capacities.

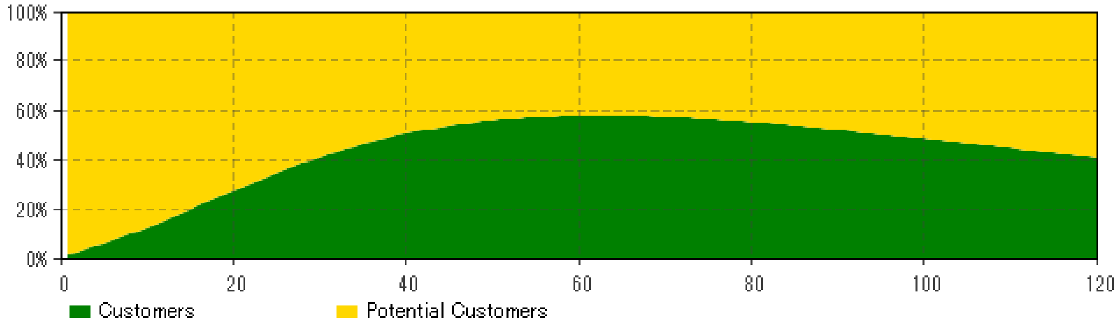


Fig. 10.20 Market Penetration (Baseline)

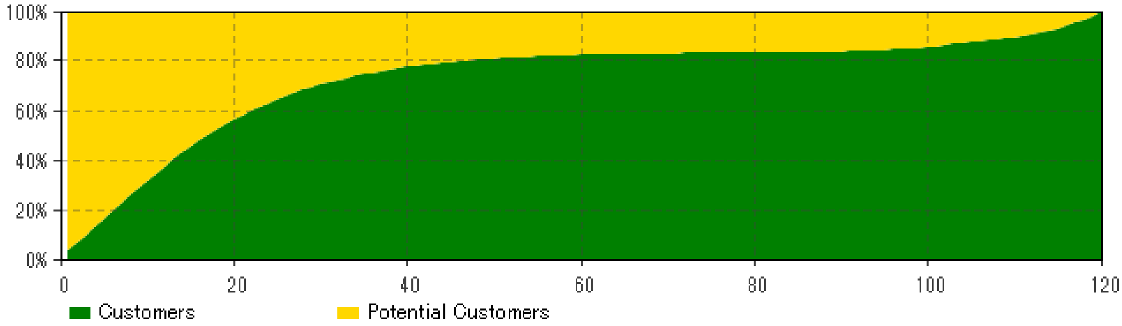


Fig. 10.21 Market Penetration (AdEffectiveness=0.03)

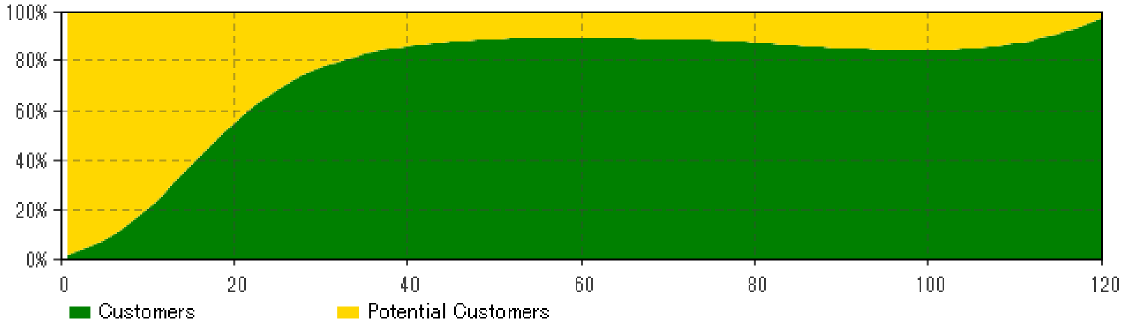


Fig. 10.22 Market Penetration (Product Attractiveness=0.1)

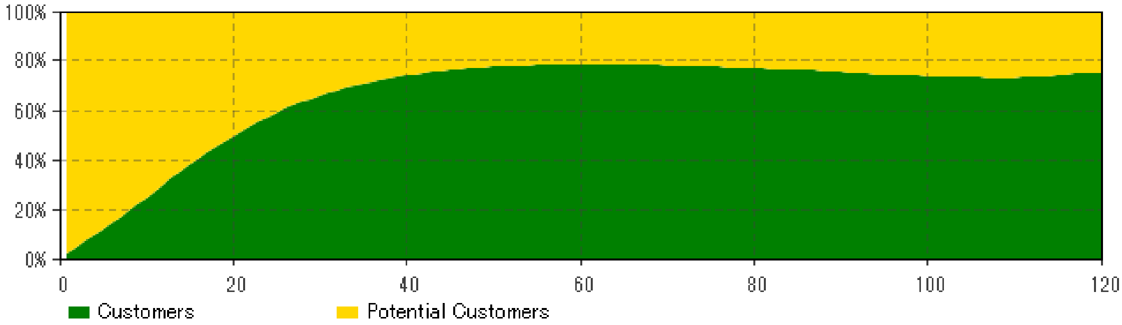


Fig. 10.23 Market Penetration (AdEffectiveness=0.02, Product Attractiveness=0.07)

Furthermore, the proposed method includes new employment required by the growth and labour adjustment according to slowdown of sales. Fig. 10.24 shows the number of employees in a company under the baseline setting. It illustrates that the company rapidly grows according to the increase of customer order. The company is required to employ more labors to increase production capacity to meet the demand. The trend continues in the beginning of the simulation but the number of employees turns to decrease around the end of the second year. It means that the market is saturated and over capacity become a critical issue for business management. It shows when a company is likely to face lay-off of its employee but with the simulation result it can prepare a well-balanced employment plan which can minimize unnecessary lay-off.

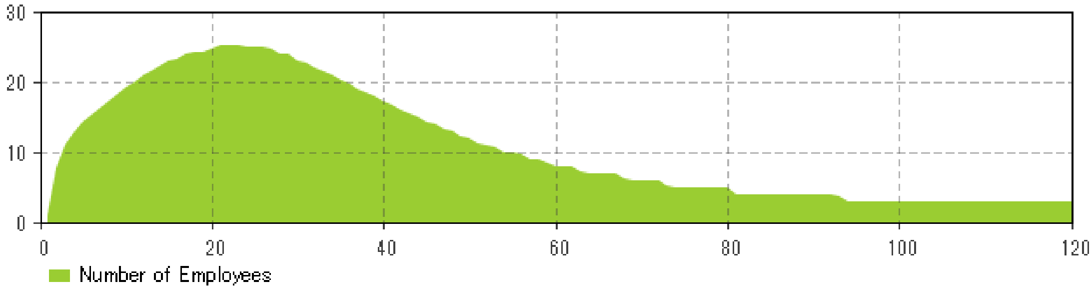


Fig. 10.24 Corporate growth and labour adjustment (Baseline)

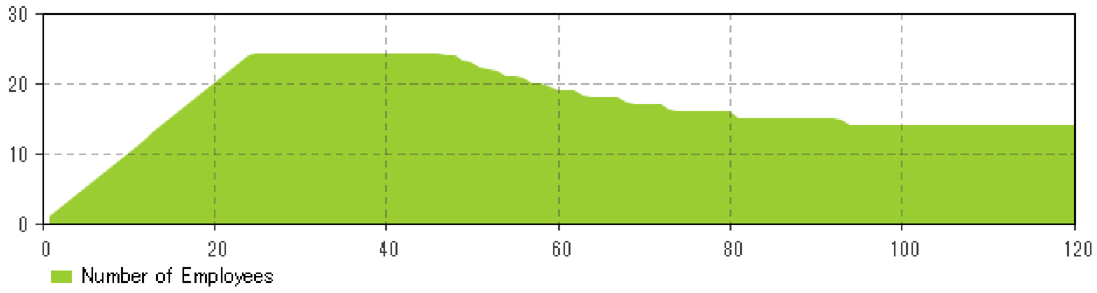


Fig. 10.25 Corporate growth and labour adjustment (Labor Adjustment Rate=12)

The baseline setting assumes that a company would employ and adjust its labour every month and therefore set the labour adjustment time as 1 month. But some company recruits new employees only one in a year. So I changed the initial value setting of Labor Adjustment Time from 1month to 12 months and rerun the simulation. Fig. 10.25 shows the result. The number of employees incrementally grows in the beginning and maintains its maximum until the end of the fourth year. The horizontal peak of the mountain illustrates it (Fig. 10.25).

This change greatly affects financial results of the simulation. Fig. 10.26 shows the results of revenue, total cost and profit under Labor Adjustment Time of 12 months. Comparing with the baseline setting (Fig. 10.12), the total cost curve in the graph (Fig. 11.26) has shifted to left-hand side and it exceeds the revenue in middle of the simulation. It means negative profit rates occur as shown in Fig. 10.27. This is mainly caused by the unnecessary employment which exceeds the required production capacity to the market demand. Since Labor Adjustment Time is set as 12 month, the company cannot promptly react to lay-off its employees. The proposed method can provide insights on when a business slowdown and a company is required to lay off employee so it can contribute to design sustainable growth of a business.

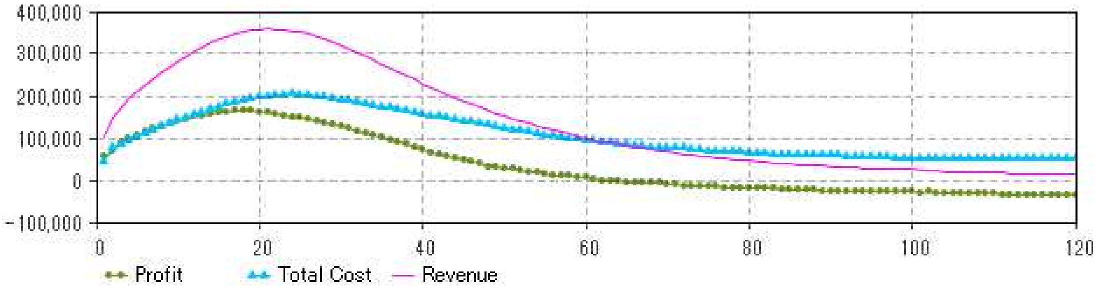


Fig. 10.26 Revenue, Total Costs, Profits (Labor Adjustment Rate=12)

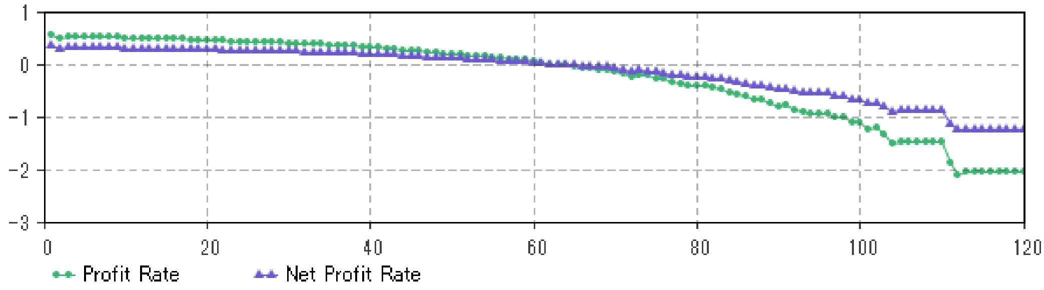


Fig. 10.27 Profit Rate and Net Profit Rate (Labor Adjustment Rate=12)

Table 10.3 Assumptions for simulation (Baseline)

Variables	Value	Unit
Market Size	10,000	person
Contact Rate	2	person/month
Ad Effectiveness	0.01	%
Product Attractiveness	0.05	%
Initial Sales per Customers	1	product/person
Average Consumption per Customers	0.01	product/person
Delivery Time	1	month
Production Time	1	month
Supply Time	1	month
Labor Adjustment Time	1	month
Discard Rate	0.05	%
Sales Price	1500	$/product
Production per Employee	10	person
Initial Employees	1	person
Initial Materials	200	product
Initial Inventory	100	product
Unit Distribution Cost	100	$/product
Unit Production Cost	200	$/product
Unit Material Cost	200	$/product
Unit Labor Cost	2,000	$/person
Rent	10,000	$/month
Admin Cost Rate	0.15	%
Tax Rate	0.4	%
Discount Rate	0.05	%
Default Rate	0.01	%
Payment Delay	0	month

Depreciation Rate	0.1	%
Investment Rate	0.1	%
Initial Investment	1000000	$

10.5. Validation

As a validation of the proposed method, I assessed superiority of the method by comparing with other conventional evaluation methods. This validation was conducted as a part of joint research activities with a company that actually implements new business development activities. I asked 7 employees of the company (staffs of the new business development office) to be examinees and to use four different methods for designing and evaluating a new business. I introduced analytical hierarchy process (AHP) method which is a combination of subjective judgement and systems approach (Ikeda et al., 2011). It enables to make a decision on multiple alternatives according to multiple criteria and the decision structure can be visualized in three layers: Goal (Top), Criteria (Middle) and Alternatives (Bottom) as shown in Fig. 10.28.

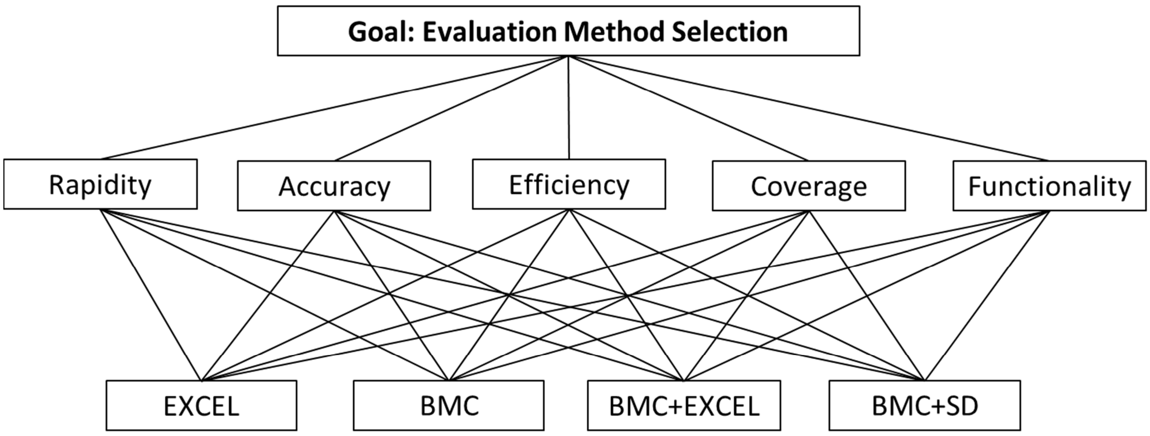


Fig. 10.28 Structuration of decision making with AHP

On the top of Fig. 10.28, the goal was defined as evaluation of method selection. In the middle shows the five criteria: (1) rapidity, (2) accuracy, (3) efficiency, (4) coverage, (5) functionality are used to evaluate each methods using pairwise comparison. Pairwise comparison is a mean to compare two different items individually and provide evaluations according to the scales (1~9) shown in Table 10.4. By comparing an item on the left and one on the right, I put the score of 9 (extremely good), 7 (very good), 5 (moderately good), 3 (fairy good) and 1 (neutral) for one side and its inverse number for the other side. First, I asked the examinees to answer the importance of each evaluation criteria using pairwise comparison seeking the geometric mean of the pairwise comparison matrix and then normalized the result to acquire the relative weight of each criterion. The consistency index (C.I.) was calculated in Eq. (10.27) to be less than 0.1 so the comparison results become consistent and reliable for analysis (Ikeda et al., 2011). The results shows that rapidity (0.35), accuracy (0.14), efficiency (0.12), coverage (0.28) and functionality (0.12). It implies the relatively high importance of speed and comprehensiveness of analysis in business creation practice. Next I asked the examinees to evaluate each method according to each criterion using the same pairwise comparison (Table 10.4). At the bottom of Fig. 10.6, there are four methods: (A) proposed method, (B) BMC only, (C) BMC + EXCEL, and (D) EXCEL. I calculated the geometric mean of the pairwise comparison matrix and then normalized the result to acquire the relative score of each method to each criterion. The consistency index was calculated to be less than 0.1 for all the comparison so the results were reliable for analysis (Ikeda et al., 2011). The results are summarized in Table 10.5.

Table 10.4 Pairwise comparison matrix

	Extremely Good		Very Good		Moderately Good		Fairly Good		Neutral		Fairy Good		Moderately Good		Very Good		Extremely Good	
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
Item																		Item

$$\text{Consistency Index (C.I.)} = \frac{\lambda_{max} - n}{n - 1}$$

Eq. (10.27)

λ_{max}: Eigen Value of the Pairwise Comparison Matrix

n: the number of items included in the Pairwise Comparison

Regarding the total score, the highest score was the proposed method (0.46) followed by BMC+EXCEL (0.26), BMC only (0.17) and Excel only (0.11). It implies that the proposed method hold overall superiority to the other methods. In addition, the proposed method is considered to hold almost the same level of accuracy as the most popular method of creating a spread sheet using EXCEL. Furthermore, it acquired the better scores to Excel in efficiency, coverage and functionality as well. Regarding rapidity, BMC and the proposed method acquired the same score (0.12). It implies that transformation process from qualitative business concept to quantitative simulation model was smoothly conducted by the examinees without considerable amount of time delay. The propose method does not have any low score in all the criteria so I think that it can be applicable to business practices.

Table 10.5 Comparison Results of Proposed Method and Conventional Methods (n=7)

		Evaluation Criteria					
		Rapidity	Accuracy	Efficiency	Coverage	Functionality	Total Score
Alternative	Proposed	0.12	0.06	0.05	0.15	0.07	0.46
	BMC Only	0.12	0.01	0.02	0.02	0.01	0.17
	BMC+EXCEL	0.06	0.06	0.03	0.08	0.03	0.26
	EXCEL Only	0.04	0.01	0.02	0.02	0.01	0.11

10.6. Chapter Conclusions

This chapter discussed a new method that integrates system dynamics and Business Model Canvas. The aim was to realize seamless concept generation and its evaluation on business system. With design thinking technique, a business concept is firstly generated and visualized using BMC. The business elements are converted into variables using BMC-SD conversion matrix for system dynamics modelling and simulation. I conducted an experiment applying the method to business 7 practitioners and assessed the advantages using AHP (Analytical Hierarchy Process). The results shows that the propose method can evaluate business feasibility, profitability and growth ability more effectively and efficiently comparing with the other conventional methods for evaluating business.

The proposed systems evaluation method can contribute especially in the early stage of business design. In design phase, it is necessary to test several hypothesise quickly on customers, market, and business model and so on under uncertain and insufficient information. The consistency of design thinking and dynamic modelling and simulation can save the time of evaluation which brings about time advantage of business competition. Furthermore, I think that the method can contribute to entrepreneurship education as well. Generating innovative ideas is very important and design thinking is effective for the purpose but it is not good enough to success of business. It is worth learning for students to identify each business element and to understand dynamic and complex interaction of human, cash, material and information within a business system.

I finally would like to point out the following two topics as future researches. The first is the precise measurement of the effectiveness in business design activities. In this research I used AHP for subjectively assessing the effectiveness of the method. Future work is to implement quantitative and objective measurement such as time saving effect of the method. The second is to increase variety of business models that can be designed by the method. The current model can simulate a product-oriented business but I will build models for service-oriented and platform-oriented business in the future. For such purpose, I consider introduction of different simulation techniques such as discrete event simulation and multi-agent simulation for describing more complex business systems.

(Intentionally Blank)

PART 5

Conclusions

(Intentionally Blank)

Chapter 11. Conclusions

11.1. Summary of Discussions

All companies today are required to consider sustainability of business balancing their short-term profitability and long-term operations within a society and natural environments. Without sustainability consideration, a business cannot expect its continuous success any more. However, we do not hold an established methodology to evaluate sustainability of business systems. I think the lack of the methodology resulted in a lot of bankruptcy and undergrowth of venture companies today. Therefore, this research aims to propose an integrated methodology to evaluate sustainability of business systems. In addition, following the research motives originated from my work experiences in aerospace sector, I applied the methodology for transforming unprofitable regional air transportation to be a more self-sustained system.

Though regional air transportation carries a relatively high business risk because of the thin and fluctuating air traffic demand, it often plays an important role in the life and economy of local regions. When the average air traffic demand is above the break-even level, regional air transport is likely to be autonomously sustained by the private sector. However, the situation is different for most regional air transportation systems.

Furthermore, the continuing air deregulation has promoted market competition among airlines. The trend has made it more difficult to sustain unprofitable regional airways through revenue pooling within private companies, resulting in withdrawal from unprofitable regional airways and the consequent decay of regional air transport networks. Government has provided various financial supports for maintaining unprofitable regional airways, but studies have criticized the inefficiency of such public assistance. Nobody, to the best of my knowledge, has explored the possibility of sustaining a regional air transport system introducing a concept of symbiosis. This research is the first to focus on the challenge of designing a more self-sustaining regional air transportation system in which regional air transport stakeholders collaborate to coexist in the market.

In Part 1, I addressed the issues of regional air transport system and of evaluating sustainability of business systems in Chapter 1 and then reviewed the literature concerning regional air transport system sustainability evaluation in Chapter 2. In Chapter 3, I introduced the systems evaluation framework and modelling technologies. Originality of my research lies in the introduction of symbiotic sustainability and the decomposition of the evaluation framework into stability, durability and scalability of business systems. According to the characteristics of issue, purpose of evaluation and availability of data and so on, I selected an appropriate technology to evaluate business systems (Fig 11.1). The inter-disciplinary, multi-methods approach is one of the strength of this research.

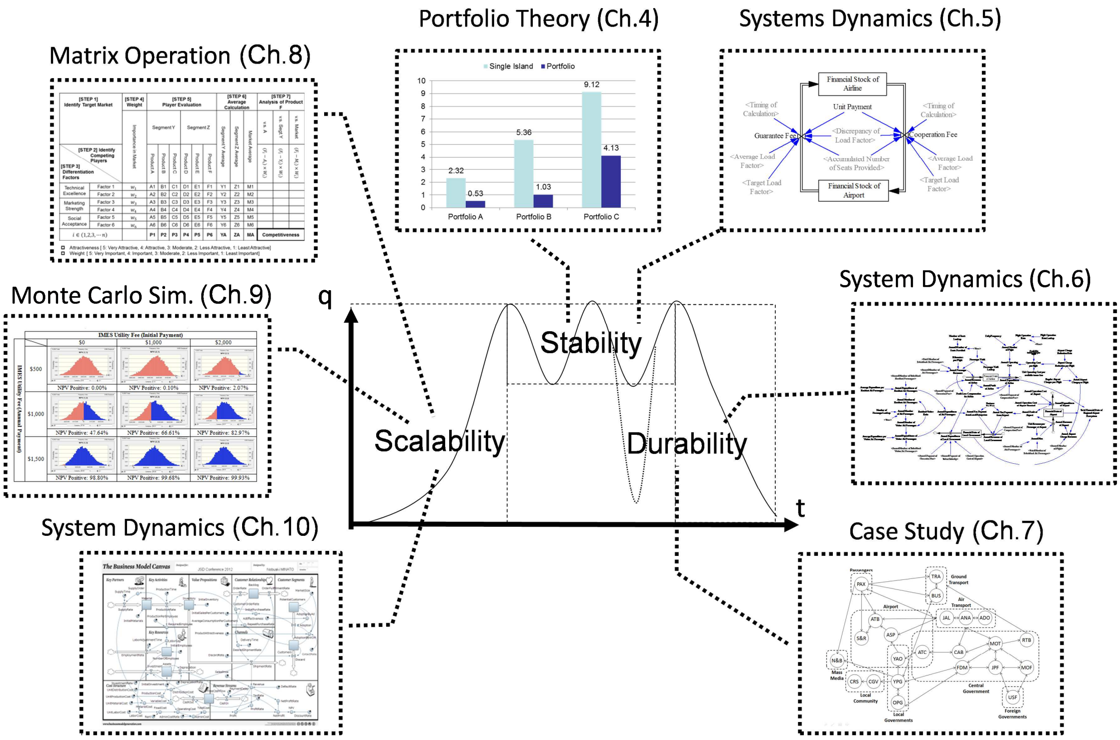


Fig. 11.1 Business systems evaluation and applied technologies

In Part 2, I discussed stability of business systems. It is of great importance when business systems are in maturity stage of their lifecycle. Since growth of business is already finished, oscillation is a major concern for business sustainability. What I proposed was to focus on sustaining MVBS within the scope of business systems. Balancing the benefit and the risk between the MVBP was the key for stability of business systems. I examined two cases in regional air transportation. The first case addressed an issue of risk diversification. The result shows that it is worth considering the integration of multiple regional airways that are not individually commercially sustainable. As variances in air traffic demand make it more difficult to manage regional air transport, the portfolio theory drawn from financial analysis has been used to consider ways of reducing business risks by diversifying destinations. The results show that a well-diversified portfolio of multiple remote islands could reduce the commercial risk score for carriers. By combining multiple regional airways with different traffic movements, a symbiosis of airlines can be designed.

The second issue addressed was risk sharing. When combining multiple airways in order to manage a single airway is not possible and when future air traffic demand is still uncertain, it is worth considering obtaining a mutual commitment from an airport and airline to sustainably operate the regional airway. I have examined the validity of the load factor guarantee scheme enabling airlines to maintain load factors above the break-even level. The airport is also encouraged to increase the number of air passengers from the local community to increase the load factor. By committing to a load factor, a symbiosis between an airport and an airline can be designed.

In Part 3, I discussed durability of business systems. It is of great importance when business systems are in decay stage of their lifecycle. Since the market is not self-sustainable anymore, special treatments are required. I examined two cases again. The first case addressed an issue of preservation of business systems introducing a concept of air transport ecosystem. When air traffic demand is expected to decrease in the long run, the commitment to a load factor is unlikely to work, as neither party can guarantee the future. In such a case, it is important to share the fate of a regional air transport business among the regional air transport stakeholders. I have used system dynamics to model and analyse the inter-dependency among the multiple stakeholders and propose strategies for sustaining it as a whole. The benefit of the air transport ecosystem is that it allows each stakeholder to understand that no one can survive without the others, leading them to implement proactive and cooperative countermeasures for the healthy management of the ecosystem.

The second issue addressed was disruption of business systems. Among several examples of disruptions such as economic crisis, natural disasters and man-made accidents, I examined durability of air transport against natural disaster. The 2011 Great East Japan earthquake and tsunami event showed an example where the regional airport facilities, whose operations often considered being not commercially sustainable, can play an important role in the emergency transport management during the catastrophic natural disasters. This chapter could highlight a new raison d'etre for regional air transport system.

In Part 4, I discussed scalability of business systems. It is of great importance when business systems are in growth stage of their lifecycle. In other words, the discussions of this part can be applicable to any business since all businesses have their beginnings. I examined three cases again. Chapter 9 discussed competitiveness of business systems. I took an example of competitiveness evaluation of Japanese regional aircraft market. A systems evaluation method of Competitive Advantage Matrix (CAM) is proposed and examined. Chapter 10 treated uncertainty in business system. I took an example of Indoor Messaging Service (IMES) technology. A matrix-based uncertainty analysis was introduced for effective and efficient financial modelling and evaluation. Chapter 11 finally attempted to integrate business elements into a business system. Systems dynamics was used to integrate with design thinking method called Business Model Canvas (BMC).

The primal purpose of the research was to propose an integrated methodology to evaluate sustainability of business systems. In other word, scalability, stability and durability of business systems must be integrally evaluated. Thus I integrated the two systems evaluation frameworks for business sustainability as shown in Fig. 11.2. It indicates that there are two different dimensions of management (horizontal) and design (vertical) of business systems. Evaluation for management is conducted for stability of business systems focusing on business dimension (discussed in Part 2) and also for durability of business systems on societal dimension (discussed in Part 3). On the other hand, evaluation for design is conducted for scalability of business systems in the early stage or even before its start (discussed in Part 4). I believe that combinational usage of the evaluation framework and the system evaluation methods introduced in this research greatly contributes to evaluate sustainability of business systems.

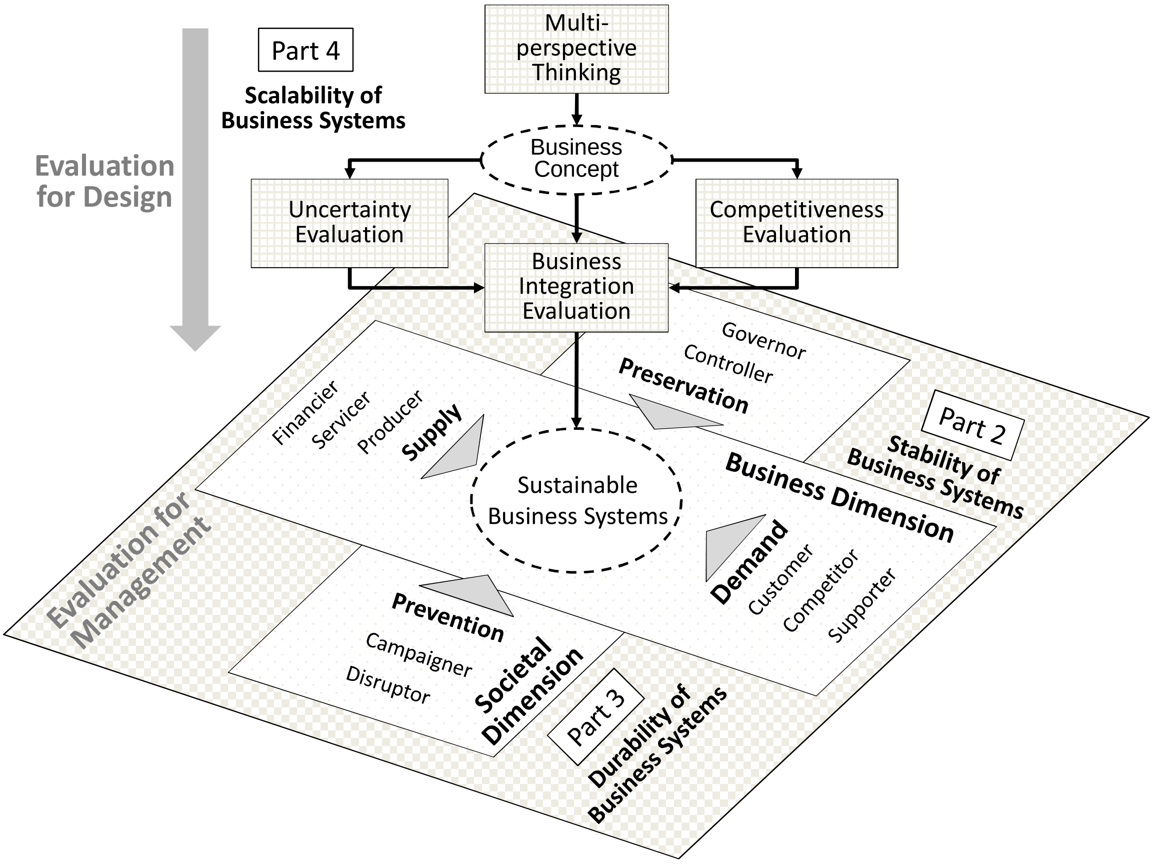


Fig. 11.2 Integrated systems evaluation framework for business sustainability

11.2. Expanded application and limitations

Regarding air transportation business in general, the globalization is an important issue. Both Airbus and Boeing forecast the incremental expansion of air traffic demand, especially in the Asian market (Global market forecast 2012–2031, Airbus, Current market outlook 2012-2-31, Boeing). Thus, I believe the research scope should be extended to trans-national air transportation services. Increasing international flights from regional airports, especially to Asian major cities, is more effective rather than expanding major airports in Japan (Takase and Morikawa, 2005). Thus, some regional airports are eager to conduct airport marketing activities to invite Asian carriers to their local cities. Unlike in the US and the European Union aviation markets, the Northeast Asian markets are still fragmented and the air transportation systems and networks in the region are very inefficient and inconvenient which is primarily caused by the restrictive bilateral air services agreements between Asian countries (Oum and Lee, 2002). Taking advantage of the stream of the open sky with foreign countries, regional air transportation can find its way to survive in the expanding market.

Moreover, 2012 is the launch year of LCCs in Japan. Three new LCCs, Peach Aviation, Air Asia Japan and Jet Star Japan, are planning to operate domestic and international short-haul flights in the near future. Although the previous research doubted the diffusion of LCCs in Asian markets pointing out the difference of market conditions and the regulatory environment (Zhang et al., 2008) with the U.S and Europe, the recent entry of LCCs could leverage the revitalisation of regional air transportation in Japan. Passengers will choose to fly from their local airport if more direct air routes to Asian large-scale hub airports are established from local airports and if transfer time at those hub airports is reduced. Consequently, passengers' convenience and satisfaction are enhanced by the increasing international flights from local airports and the country's entire air transportation system is likely to become more sustainable. The methodology proposed in this research can contributes to the realization through effective design of regional air transportation.

11.2.1. *Foreign market application and limitations*

Application of the methodology to foreign market is technically possible but I think that the following considerations are further required.

First of all, it is necessary to consider cultural aspects of management. Although I believe the methodology contributes to the global design, the effectiveness in foreign markets needs to be determined carefully by future studies, since management is strongly affected by the culture of the country where it occurs (DeFrank et al., 1985; Hope, 2004). I suspect that some friction could occur should the proposed model be applied to a Western society. It is often said that Japanese management is generally based on a bottom-up approach whereas Western management is based on a top-down approach (Martinsons and Davison, 2007). Future research should thus pursue an international comparative study that includes a cultural perspective. To this end, I have started a joint research project with Purdue University in the U.S., the Delft University of Technology in the Netherlands, and the Polytechnic di Milan in Italy.

Second, competitive environment of a market should be examined in details. In Japan, there are severe competitions between air transportation and high speed train, which greatly influences commercial sustainability of the regional air transportation. However, some country does not hold a well-established high speed train network such as U.S. and most of the Asian countries. Some country holds a well-established highway bus network that competes against air transportation with cheaper ticket price such as Turkey. High speed boat and ferry boat are still popular transportations in islander countries. The uniqueness of competitive environment requires different strategy for business sustainability. Furthermore, business sustainability is influenced not only by competition but also by cooperation with the other means of transportation. Symbiotic sustainability with other transportation measures needs to be discussed by future studies.

Finally, parameters for the simulation model must be carefully adjusted according to market conditions. For example, in this study, I set the price elasticity to demand as -0.74 considering domestic flights in Japan (Yamanouchi, 2000). However, price elasticity to demand varies according to business category, seasons, flight purpose and locations. With this respect, the global application of the model requires further survey on the information on a target country, airline, airport, government and community and so on. Macro-economic factors, socio-geographic factors and special constraints on a target country also should be investigated before the modelling and simulation process. The below are the illustration of major information and data utilized in this research. I believe it facilitate the modelling and simulation process for foreign market application using the methodology.

Table 11.1 Information collected for modelling and simulation

Category	Information
General Market Information	Population of a target country (with growth rate)
	Gross Domestic Production (GDP) (with growth rate)
	Industrial structure of a target country
	Air transportation network and passengers (network density, annual and monthly passengers, growth rate, average price, etc.)
	Highway network and passengers (private cars)
	Highway bus network and passengers
	High speed train network and passengers
	Naval transport network and passengers
	Degree of competition among transportation measures
	Seasonality (climate, holiday structure, etc.)
	Societal constraints (awareness for environment, natural disaster, labour, etc.)
Foreign Airline	Number of airlines operating in a target country
	Degree of competition among airlines operating in a target country
	Operation cost structure of a target airline
	Operational reliability of a target airline
	Number of airway operated by a target airline
	Number of flight per day operated by a target airline
	Number of flight per day for a target airway operated by a target airline
	Number of aircraft owned by a target airline
	Variety of aircraft owned by a target airline
	Size of aircraft utilized for a target airway
	Average ticket price for a target airway
	Discount scheme for a target airway offered by a target airline

Foreign Airport	Number of airports in a target country
	Degree of competition among airports in a target country
	Airport development plan in a target country
	Number of passengers utilizing a target airport (annual and monthly, growth rate)
	Operation cost structure of a target airport
	Ownership of a target airport
	Management structure of a target airport (ATC, runway, terminal buildings, etc.)
	Financing structure of a target airport
	Ground access network to a target airport (train, bus, taxi, etc.)
	Facility of a target airport (parking, restaurants, shops, etc.)
Foreign Government (Central and Local)	General policy for air transportation
	Open sky agreement
	Subsidy policy and program (central and local)
	Tax rates (fuel tax, business tax, consumer tax, etc.)
	Management structure (central and local, inter-relation)
Local Community	Number of residents (growth rate)
	Number of tourists (annual and monthly, growth rate)
	Local ground access network (density, ticket price, etc.)
	Average expenditure by residents
	Average expenditure by visitors
	Accommodation capacity
	Subsidy programs (chamber of commerce, etc.)
	Outstanding geographic characteristics (remote region, peninsula, island, inland, highland, coastal, etc.)
	Climatic constraints (heavy snow, typhoon, hot weather, etc.)

11.3. Future works

11.3.1. Risk Sharing with Local Residents as Investors

As discussed in the thesis, regional air transportation services with thin demands are usually maintained with public subsidy. This is a common practice worldwide but its sustainability is not assured in the long run in any country. Previous researches mainly discuss efficiency of air transport operation with subsidy programs but I think the core problem lies in continuous demand creation in a specific region. The current management practices lucks the perspective of risk and return sharing with local residents who are directly benefited from the air transportation services.

Hence, I propose a new financial framework called Local User Finance Initiative (LUFI) (Fig. 11.3). The hypothesis is that LUFI securitizes future cash flow of a regional transportation service and request local residents to invest for it. It implies that local residents are incentivized to utilize the air transportation services for acquiring dividends in the future. Government guarantees the minimum load factor of the transportation service to hedge the risk of commercial operators. It encourages airlines to enter commercially uncertain airways. Since the load factor is expected to be kept high with the incentive scheme, government's expenditure is also expected to be reduced.

I examine the hypothesis in three ways. First, I implement stakeholder analysis for identifying and understanding their interactions and cash flow. I build a mathematical model to simulate financial feasibility. Second, I investigate legal constraints to realize the framework. This should be done with case studies in several countries. Finally, I investigate consumer preferences toward the framework. I implement a questionnaire to ask their willingness to invest and how much for the security. The outcomes contribute to manage wider range of public transportation services other than air transportation that suffers chronic profit losses. Academically, I can formulate a new theoretical framework of public marketing by synthesizing the examinations above. This work is supported by Japan Society for the Promotion of Sciences (JSPS) KAKENHI Grant Number 25870720.

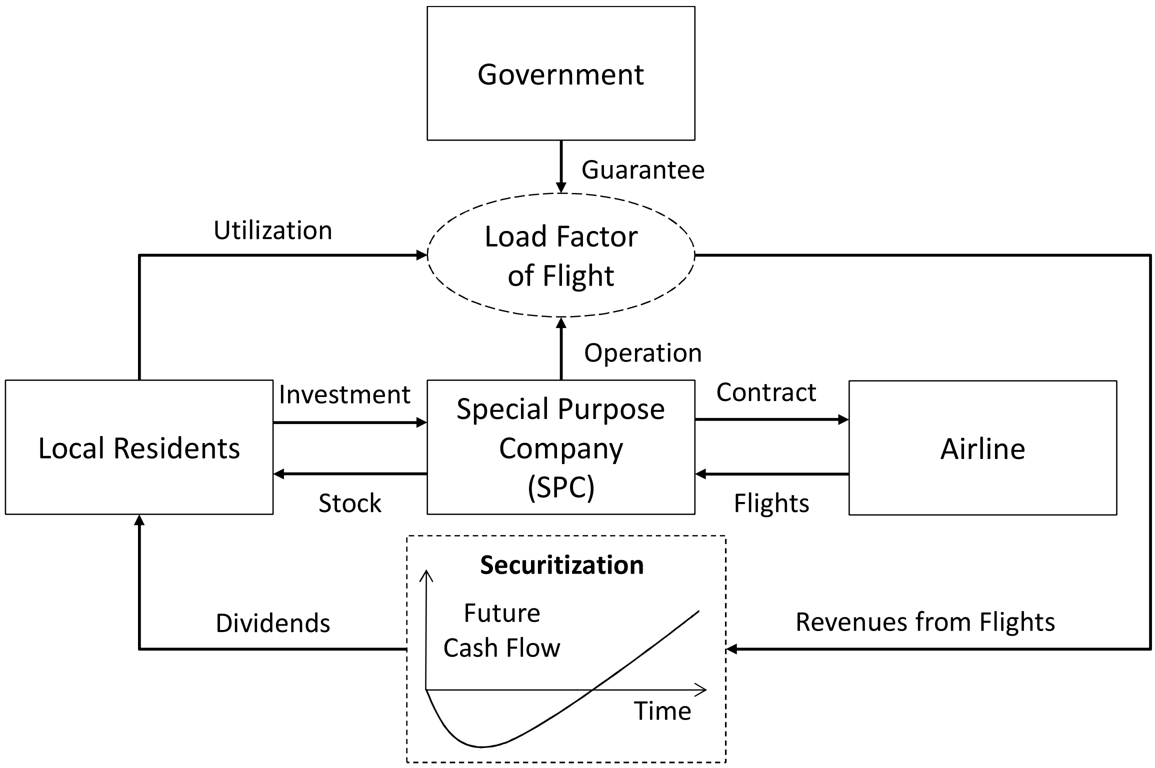


Fig. 11.3 Conceptual Framework of Local User Finance Initiative (LUFI) Model

(Intentionally Blank)

(Intentionally Blank)

References

(Intentionally Blank)

References

ACI, 2002. ACI World Report. Airports Council International.

ADP and Schiphol., 2008. Aeroports de Paris and Schiphol Group to Create a Leading Global Alliance in the Airport Industry. Press Notice, Paris, Amsterdam.

Airbus, 2012. Global market forecast 2012–2031. Last accessed on October 2012 at http://www.airbus.com/company/market/forecast/.

Airport World. 2011. Airport World: The Official Magazine of the Airports Council International. Last access on February 2012 at http://airport-world.com.

Albers, S., Koch, B., Ruff, C., 2005. Strategic alliance between airlines and airports–theoretical assessment and practical evidence. Journal of Air Transport Management 11, pp. 49-58.

Arai, K. 2004. An airline merger in Japan: a case study revealing principles of Japanese merger control. Journal of Industry, Competition and Trade, Volume 4, pp. 207–222.

Associated Press. 2010. The Guardian. Last access on February 2012 at http://www.guardian.co.uk/world/feedarticle/9032564.

Auerbach, S., & Koch, B., 2007. Cooperative Approaches to Managing Air Traffic Efficiently - The Airline Perspective. Journal of Air Transport Management, Volume 13, Issue 1, pp. 37-44.

Avion de Transport Regional (ATR), ATR 72-500 and ATR-42, 2010. Last access on May 2010 at http://www.atraircraft.com/public/atr/html/products/products.php?aid=506

Aviation Statistics, 2009. Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Government of Japan. Aviation Promotion Foundation of Japan. pp. 307-320.

Barros, C., Managi, S., Yoshida, Y. 2010. Productivity growth and biased technological change in Japanese airports. Transport Policy, Volume 17, Issue 4, pp. 259-265.

Barrett, S., 2000. Airport competition in the deregulated European aviation market. Journal of Air Transport Management, Volume 6, Issue 1, pp. 13-27.

Bass, F. 1969. A new product growth model for consumer durables, Management Science, Vol.15, pp.215-227.

BBC News Europe. 2010. BBC News Europe. Last access on February 2012 at http://www.bbc.co.uk/news/uk-12038847.

Blanchard, S., Fabrycky, J., 2006. Systems Engineering and Analysis, Fourth Edition. Prentice Hall. p. 19.

Boeing, 2012. Current market outlook 2012-2031. Last access on October 2012 at http://www.boeing.com/commercial/cmo/.

Braithwaite, G., 2001. Aviation rescue and firefighting in Australia—Is it protecting the customer? Journal of Air Transport Management, Volume 7, Issue 2, pp. 111-118.

Brundtland G, editor. 1987. Our common future: the world commission on environment and development. Chapter 2. Oxford: Oxford University Press.

Buzan, T. 2005. The Mind Map, Diamond Publishing.

Carlos P. B., Shunsuke M., Yuichiro Y., 2010. Productivity growth and biased technological change in Japanese airports, Transport Policy, Volume 17, Issue 4, pp. 259-265.

Carney, M., & Mew, K., 2003. Airport Governance Reform: A Strategic Management Perspective. Journal of Air Transport Management, Volume 9, Issue 4, pp. 221-232.

Castillo-Manzano, J., 2010. The city-airport connection in the low-cost carrier era: Implications for urban transport planning. Journal of Air Transport Management, Volume 16, Issue 6, pp. 295-298.

Center for Health Emergency Preparedness and Response. 2004. Emergency Situation Report: Earthquake in Nanggroe Aceh Darussalam Province, Indonesia. WHO Indonesia, Ministry of Health and Emergency and Humanitarian Action Section, Aceh.

Chang, Y., Hsu, C., Williams, G., Pan, M, 2008. Low cost carriers' destination selection using a Delphi method. Tourism Management, Volume 29, Issue 5, pp. 898-908.

Cidell, J., 2006. Regional cooperation and the regionalization of air travel in Central New England. Journal of Transport Geography, Volume 14, Issue 1, pp. 23-34.

Cleary, T. 2005. The Art of War. Shambhala Publication Inc. p64.

Coleman, R. 1999. Environmentally Sustainable Capacity. Proceedings of the ECAC/EU Dialogue with the European Air Transport Industry: Airport Capacity - Challenges for the Future, pp. 118-125. Salzburg: European Civil Aviation Conference.

Cox, A., Prager, F., Rose. A., 2011. Transportation security and the role of resilience: A foundation for operational metrics. Transport Policy, Volume 18, Issue 2, pp. 307-317.

DeFrank, R., Matteson, M., SchIiger, D., Ivancevich, J., 1985. The impact of culture on the management practices of American and Japanese CEOs. Organizational Dynamics, Volume 13, Issue 4, pp. 62-76.

Den Hartigh, E., Asseldonk, T., 2004. Business ecosystems: A research framework for investigating the relation between network structure, firm strategy, and the pattern of innovation diffusion; Contribution to the European Chaos/Complexity in Organizations Network (ECCON) Conference, October 2004.

Den Hartigh, E., Tol, M., Wei, J., Visscher, W., Zhao, M., 2005. Modeling a business ecosystem: An agent-based simulation. European Chaos/Complexity in Organizations Network (ECCON) Annual meeting 2005.

Doganis, R., 2001. The Airline Business in the 21st Century. London: Routledge.

Doganis, R., 2010. Flying Off Course. Airline Economics and Marketing. Fourth Edition. Routledge, pp.42-45, pp. 86-96, p. 198.

East Japan Railway Company (JR East), 2011. Last accessed on September 2011 at http://www.jreast.co.jp/e/index.html.

Ehmer, H. 2001. Liberalization in German air transport — analysis and competition policy recommendations: Summary of a German study. Journal of Air Transport Management, Volume 7, Issue 1, pp. 51-55.

Endo, N. 2007. International trade in air transport services: Penetration of foreign airlines into Japan under the bilateral aviation policies of the US and Japan. Journal of Air Transport Management, Volume 13, Issue 5, pp. 285-292.

Epley, EE., et al., 2006. A regional medical operations center improves disaster response and inter-hospital trauma transfer. The American Journal of Surgery, Voume 192, Issue 6, pp. 853-859.

EU Business. 2011. Last access on February 2012 at http://www.eubusiness.com/news.

Eurocontrol, 2006. Basic CFMU Handbook: ATFCM, User’s Manual Edition 11.0.

Eurocontrol, 2004. Evaluating the True Cost to Airlines of One Minute of Airborne or Ground Delay.

Feldhoff, T., 2002. Japan's regional airports: conflicting national, regional and local interests, Journal of Transport Geography, Volume 10, Issue 3, pp. 165-175.

Feldhoff, T., 2003. Japan’s capital Tokyo and its airports: problems and prospects from subnational and supranational perspectives, Journal of Air Transport Management, Volume 9, Issue 4, pp. 241-254.

Fenley, C., Machado, W., Fenandes, E. 2007. Air transport and sustainability: Lessons from Amazonas. Geoforum, Volume 39, Issue 2, pp. 63-77.

Fire and Disaster Management Agency of Japan (FDMA). Last accessed on September 2011at http://www.fdma.go.jp/.

Forsyth, P., Niemeier, H.-M., & Wolf, H., 2011. Airport Alliances and Mergers - Structural Change in the Airport Industry? Journal of Air Transport Management, Volume 17, Issue 1, pp. 49-56.

Fukushima, Y., Okubo, T., 2009. Research on Human Participation of Avoidance in Traditional Measures for Disaster Mitigation. Architectural Institute of Japan. Kinki region. Volume 49, pp. 297-300 (in Japanese).

Fukuyama, T., Kagawa, T., Ikeda, Y., 2009. Analyses on international airways at Yonago Airport in Japan: Benefit and bargaining of local government. IATSS Review, Volume 34, Issue 1, pp. 90-98.

Garriaga, J. C., 2003. Airport Dynamics: Towards Airport Systems. Airport Regions Conference. ARC Transport Interest Group.

Graham, A., 2003. Managing Airports—An international perspective, Second edition, Elsevier Ltd., Oxford, U.K., pp. 8, pp. 179, pp. 203-216.

Graham, A., 2006. Competition in airprots. Corporate rival and market power. I.B. Tauris & Co.Ltd. Chpter 5, pp. 76-93.

Graham, B., Guyer, C., 2000. The role of regional airports and air services in the United Kingdom. Journal of Transport Geography Volume 8, Issue 4, pp. 249-262.

Grubesic, T., Matisiw, T., 2011. A spatial analysis of air transport access and the essential air service program in the United States. Journal of Transport Geography, Volume 19, Issue 1, pp. 93-105.

Gudmundsson, S., Anger, A. 2012. Global carbon dioxide emissions scenarios for aviation derived from IPCC storylines: A meta-analysis. Transportation Research Part D: Transport and Environment, Volume 17, Issue 1, pp. 61-65.

Gunasekaran, A., Spalanzani, A. 2012. Sustainability of manufacturing and services: Investigations for research and applications. International Journal of Production Economics, Volume 140, Issue 1, pp. 35-47.

Harvey, G., 1987. Airport Choice in a Multiple Airport Region. Transportation Research A , Volume 21, Issue 6, pp. 439-449.

Halpern, H., 2010. Marketing innovation: Sources, capabilities and consequences at airports in Europe's peripheral areas. Journal of Air Transport Management, Volume 16, Issue 2, pp. 52-58.

Hanaoka, S., Saraswati, B. Low cost airport terminal locations and configurations. Journal of Air Transport Management, Volume 17, Issue 5, pp. 314-319.

Hashimoto, N, 2011. Utilization of Fukushima airport at the 2011 East Japan earthquake and tsunami (Fukushima no shinro), Volume 374, pp. 35-38 (in Japanese).

Hihara, K., 2007. Quantitative Analysis about the Payoffs of 'Load Factor Guarantee Mechanism' for Noto Airport. Journal of Japanese Society of Transport Economics, Volume 51, pp. 169-178 (in Japanese).

Hihara, K. 2011. An Analysis on Airport-Airline Vertical Relationships with Risk Sharing Contracts under Asymmetric Information Structures. Procedia - Social and Behavioral Sciences, Volume 20, pp. 1090-1098.

Hihara, K. 2012. An analysis of an airport–airline relationship under a risk sharing contract. Transportation Research Part E: Logistics and Transportation Review, Volume 48, Issue 5, pp. 978-992.

Hino, S., Kishi, K., Satho, K., 2006. A possibility of the regional airline service in local area from the viewpoint of airfares. Research reports of Akita National College of Technology, Volume 41, pp. 40-48 (in Japanese).

Hooper, P. 2002. Privatization of airports in Asia. Journal of Air Transport Management, Volume 8, Issue 5, pp. 289-300.

Hope, C., 2004. The impact of national culture on the transfer of 'best practice operations management' in hotels in St. Lucia. Tourism Management, Volume 25, Issue 1, pp. 45-59.

Hutchins, M., Sutherland, J., 2008. An exploration of measures of social sustainability and their application to supply chain decisions. Journal of Cleaner Production, Volume 16, pp. 1688-1698.

Huffington Post. 2011. The Huffington Post - World. Last access on February 2012 at http://www.huffingtonpost.com/2011/10/25/thailand-floods-2011-don-muang_n_1030074.html.

Human Development Forum Foundation. 2011. HDFF Thailand Flood 2011 Special. Human Development Forum Foundation.

Humphreys, I., Francis, G., 2002a. Performance measurement: A review of airports. International Journal of Transport Management, Volume 1, Issue 2, pp. 79-85.

Humphreys, I., Francis, G., 2002b. Policy issues and planning of UK regional airports. Journal of Transport Geography, Volume 10, Issue 4, pp. 249-258.

Iansiti, M., Levin, R., 2004. Strategy as ecology. Harvard Business Review. Volume 83, Issue 2, pp. 68-78.

Ikeda, A., Inoue, M.. 2011. Shinkai systems engineering- method of planning and analysis, Ohmu-sha, pp. 1- 30 (in Japanese).

INCOSE Systems Engineering Handbook, 2010. Version 3.2. International Council of Systems Engineering, p.12, p.59, p. 362.

Inoue, Y., 2008. Air Transport Business. Nihon-Hyouron Publishing, Japan, pp. 177-193 (in Japanese).

Japan Air Commuter (JAC), Official website. Last accessed in August 2010 at http://www.jac.co.jp/.

Japan Seismic Hazard Information Station, National Research Institute for Earth Science and Disaster Prevention. Last accessed on October 2012 at http://www.j-shis.bosai.go.jp/?lang=en.

Jarach, D., 2005. Airport Marketing strategies to cope with the new millennium environment. Ashgate Publishing Limited, England, pp. 1-11.

Kato, K., Uemura, T., Indo, Y., Okada, A., Tanabe, K., Saito, S., Oguma, H., Yamauchi, H., Shiomi, E., Saegusa, M., Migita, K., 2011. Journal of Air Transport Management, Volume 17, Issue 2, pp. 88-93.

Kawai, K., 2004. Social project management. Journal of the Society of Project Management, Volume 6, Issue 5, pp. 5-10 (in Japanese).

Kim, Sun K, Minato, N., Busser, D., Kohtake, N. 2010. Transforming Seamless Positioning Technology into a Business using a Systems Design Approach-Scenario-based Amorphous Design. Proceeding of IEEE-International Systems Conference. San Diego, USA 2010.

Kita, H., Koike, A., Tanimoto, K., 2005. Air service development of local airports and its influence on the formation of aviation networks. Research in Transportation Economics, Volume 13, pp. 223-249.

Kobayashi, K., Tanaka, T., 2006. Study of helicopter operation management for disaster relief (1): Research and analysis of helicopter operations on NIIGATA CHUETSU Earthquake. Journal of Natural Disaster Science, Volume 24, Issue 2, pp. 387-407 (in Japanese).

Kondo, T., Nagamatsu, S., 2007. Emergency response applying Incident Command System by local government—A case study on 2005 Hurricane Katrina Disaster, Journal of Social Safety Science, Volume 9, pp. 253-260 (in Japanese).

Kumagai, Y., Tahara, Y., 1996. A comparative study on emergency responses between the Great Hanshin-Awaji Earthquake and Northridge Earthquake. Journal of Social Safety Science, Volume 6, pp. 327-336 (in Japanese).

Lamberton, G. 2005. Sustainability accounting. Accounting Forum, Vlume 29, pp. 7-26.

Lei, Z., Papatheodorou, A., 2010. Measuring the effect of low-cost carriers on regional airports' commercial revenue. Research in Transport Economics, Volume 26, Issue 1, pp. 37-43.

Lian, J., Ronnevik, J., 2011. Airport competition—Regional airports losing ground to main airports. Journal of Transport Geography, Volume 19, Issue 1, pp. 85-92.

Lien, G., Hardaker, J., Flaten, O., 2007. Risk and economic sustainability of crop farming system. Agricultural systems, Volume 94, pp. 541-552.

Lieshout, R., Matsumoto, H. 2012.New international services and the competitiveness of Tokyo International Airport. Journal of Transport Geography, Volume 22, pp. 53-64.

INCOSE, 2010. Systems Engineering Handbook. Version 3.2. International Council of Systems Engineering, p.12, p.59, p. 362.

London Luton Airport Operations, Ltd., 2000. Development Brief. London Luton Airport Operations Ltd. Dorset: Terence O'Rourke plc.

Lyneis, J., 2000. System dynamics for market forecasting and structural analysis. System Dynamics Review, Volume 16, Issue 1, pp. 3-25.

Maddison, D. (1993). The True Costs of Road Transport. London: Earthscan.

Marcucci, E., Gatta, V., 2011. Regional airport choice: Consumer behavior and policy implications. Journal of Transport Geography, Volume 19, Issue 1, pp. 70-84.

Martinsons, M., Davison, R., 2007. Strategic decision making and support systems: Comparing American, Japanese and Chinese management. Decision Support Systems, Volume 43, Issue 1, pp. 284-300.

Matisziw, T., Lee, C., Grubesic, T., 2012. An analysis of essential air service structure and performance. Journal of Air Transport Management, Volume 18, Issue 1, January 2012, pp. 5-11.

Matsumoto, I., 2007. A Study of the Air Routes and the Airports in 5 isolated Islands in Nagasaki. Nagasaki Prefectural University Journal, Volume 41, Issue 3, pp. 111-186 (in Japanese).

Miller, B., Clarke, J., 2007. The hidden value of air transportation infrastructure. Technological Forecasting and Social Change, Volume 74, Issue 1, pp. 18-35.

Minato, N., Morimoto, R., 2010. Sustainable airline strategy using portfolio theory: A case study of remote islands in Japan. Journal of Air Transport Management, Volume 17, Issue 3, pp. 195-198.

Minato, N., Morimoto, R., 2011a. Designing commercial sustainability of unprofitable regional airport using system dynamics analysis. Research in Transport Business and Management, Volume 1, Issue 1, pp. 80-90.

Minato, N., and Morimoto, R., 2011b. Policy design for sustainable regional air transport using load factor guarantee. Japanese Journal of System Dynamics, Volume 10, pp. 13-24 (in Japanese).

Minato, N., Morimoto, R. 2012. Collaborative management of regional air transport during natural disasters: Case of the 2011 East Japan earthquake and tsunami. Research in Transport Business and Management. Research in Transport Business and Management, Volume 4, Issue 1, pp.13-21.

Minato, N., Morimoto, R., 2012. System Dynamics Analysis on a Management of Airline-Airport Coexistence with a Load Factor Guarantee. Proceedings of International System Dynamics Conference 2012. St. Gallen, Switzerland. July 2012.

Minato, N., Utsumi, Y., 2010. Restructuring Japanese regional air transport system with Chofu airport in Tokyo. Proceedings of ATRS2010. Port, Portugal, July 2010.

Ministry of Economy, Trade and Industry, 2010. Survey on growth and development of local economy and enterprise.

Ministry of Economy, Trade and Industry, 2012. Frontier human resources Study Group Report.

Ministry of Finance (MOF), Government of Japan, 2011. Last accessed on January 2013 at http://www.mof.go.jp/tax_policy/summary/condition/007.htm

Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Government of Japan, 2010. Report on the Noto Airport, pp. 103-109.

Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Government of Japan, 2012. Official Website. Last accessed on October 2012 at http://www.mlit.go.jp/en/index.html

Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Government of Japan, 2012. Air transport statistics. Last accessed on October 2012 at http://www.mlit.go.jp/en/index.html

Mizutani, J. 2011. Airline merger and competition in Japan: A conduct parameter and theoretical price approach. Journal of Air Transport Management, Volume 17, Issue 2, pp. 120–124.

Moore, J. F., 1993. Predators and prey: A new ecology of competition. Harvard Business Review. Volume 71, Issue 3, pp. 75-86.

Morimoto, R. 2010. Estimating the benefits of effectively and proactively maintaining infrastructure with the innovative Smart Infrastructure sensor system. Socio-Economic Planning Sciences, Volume 44, pp. 247-257.

Murakami, H., Kato, I., Takahashi, N., Sakakibara, H., 2008. Economics of Aviation, Minerbashobo, pp. 59-64 (in Japanese).

Nakagawa, D., Aoyama, Y., Ito, T., Nishizawa, H. 2005. Assessment of passenger benefits brought about by international airport projects. Transport Policy, Volume 12, Issue 6, pp. 512-524.

Nakano, M. 2010. A conceptual framework for sustainable manufacturing by focusing on risk and supply chains. APMS 2009,IFIP AICT 338, pp. 160-167, Springer.

Nakano, M., Minato, N., 2012. Systems approach for business engineering. Kodansha publishing. pp. 79-88 (in Japanese).

National Institute of Japanese Island (NIJI), 2007. Remote Island Statistics.

Neufville, R. d., 2000. Planning Multi-Airport Systems in Metropolitan Regions in The 1990s: A Policy Guide Based Upon The Analysis of Experience at Existing Multi-Airport Systems. Cambridge: Massachusetts Institute of Technology.

New Central Air Service (NCA), 2012. Official Website. Last accessed on October 2012 at http://www.central-air.co.jp/index.html.

Nidumolu, U., Keulen, H., Lubbers, M., Mapfumo, A., 2007. Combining interactive multiple goal linear programming with an inter-stakeholder communication matrix to generate land use options. Environmental Modeling & Software, Volume 22, Issue 1, pp. 73-83.

Nomura, S., Kiritooshi, K., 2010. Aviation globalization and airport business. Doubun-kan, Japan, pp. 89-98, pp. 160-161 (in Japanese).

Noto Airport Promotion Council (NAPC), 2012. Last accessed on March 2012 at http://www.noto-airport.jp/.

Nucciarelli, A., Gastaldi, M., 2009. Collaboration in the airport business through the development of an IT platform. International Journal of Production Economics, Volume 121, Issue 2, pp. 562-573.

O'Connell, J. F., Williams, G., 2005. Passengers' perceptions of low cost airlines and full service carriers: a case study involving Ryanair, Air Lingus, Air Asia and Malaysia Airlines. Journal of Air Transport Management, Volume 11, Issue 4, pp. 259-272.

Odani, M., Uranaka, K., Sanko, T., 2000. Analysis of traffic situation in disaster area after the Great Hanshin-Awaji Earthquake by using aerial photos. Infrastructure Planning Review, Volume 18, pp. 849-858 (in Japanese).

Ohta, K. 1999. International airports: financing methods in Japan. Journal of Air Transport Management, Volume 5, Issue 4, pp. 223-234.

Okamura, S., Minato, N., 2012. Big Society: the deterrent against the dynamics of government debt expansion. Japanese Journal of System Dynamics. Volume 11, pp. 17-32 (in Japanese).

Ostarwalder, A., Pigneur, Y., 2010. Business Model Generation, Shoeisha, 2010.

Oum, T., Lee, Y. 2002. J The Northeast Asian air transport network: is there a possibility of creating Open Skies in the region? Journal of Air Transport Management, Volume 8, Issue 5, pp. 325-377.

Papatheodorou, A., Lei, Z., 2006. Leisure travel in Europe and airline business models: A study of regional airports in Great Britain. Journal of Air Transport Management, Volume 12, Issue 1, pp. 47-52.

Pearce, B. 2012. The state of air transport markets and the airline industry after the great recession. Journal of Air Transport Management, Volume 21, pp. 3-9.

Pejovic, T., Noland, R. B., Williams, V., & Toumi, R., 2009. A Tentative Analysis of The Impacts of an Airport Closure. Journal of Air Transport Management, Volume 15, Issue 5, pp. 241-248.

Port and Airport Research Institute, 2011. Technical note of the port and airport research institute. Volume1231. ISSN1346-7840. April 2011.

Raymer, D. P., 2006. Aircraft Design: A Conceptual Approach, Fourth edition, American Institute of Aeronautics and Astronautics.

Research Institute of Economy, Trade and Industry (RIETI), 2007. Study on regional airport governance system. Discussion Paper Series 07-J-045, November 2007.

Santana, I., 2009. Do public service obligations hamper the cost competitiveness of regional airlines? Journal of Air Transport Management, Volume 15, Issue 6, pp. 344-349.

Savitz, W., Weber, K. 2006. The triple bottom line: How today's best-run companies are achieving economic, social and environmental success and how you can too. San Francisco, CA.

Sato, K., Takano, N., Igarashi, H., 1990. Introduction program of regional air transportation. Proceedings of Operation Research Society of Japan. Spring 1990 (in Japanese).

Sendai Airport Transit Co. Ltd. (SAT), 2011. Official website. Last accessed on September 2011 at http://www.senat.co.jp/.

Sengupta, S., & Perry, M., 1997. Some Antecedents of Global Strategic Alliance Formation. Journal of International Marketing, Volume 5, pp.31-50.

Sharma, A., Lyer, g., Mehrotra, A., Krishnan, R. 2010. Sustainability and business-to-business marketing: A framework and implications. Industrial Marketing Management, Volume 39, pp. 330-341.

Sightseeing Statistics of Ishikawa Prefecture, 2009. Department of transport and sightseeing. Prefecture of Ishikawa. Last accessed on September 2011 at http://toukei.pref.ishikawa.jp/index.asp.

Smith, J., 2010. Regional cooperation, coordination and communication between airports during disaster. Journal of Transportation Research Board. pp. 132-140. DOI: 10.3141/2177-16.

Sterman, J., 2000. Business dynamics—Systems thinking and modeling for a complex world. McGraw Hill Higher Education, U.S.A., pp. 11, pp. 192, pp. 229.

Stevenson, J. A. 2012. Last access on April 2012 at http://all-geo.org/volcan01010/2012/04/

Sunnucks, M., 2002. Dulles Looks to Load Up on Cargo. Washington Business Journal. Last accessed on October 2012 at www.washington/bizjournals.com.

Suryani, E., Chou, S., Chen, C., 2010. Air passenger demand forecasting and passenger terminal capacity expansion: A system dynamics framework. Expert Systems with Applications, Volume 37, Issue 3, pp. 2324-2339.

Suzuki, K., Takano, N., and Sato, K., 1995. A study of demand forecast model for commuter airlines. Journal of Japan Society of Civil Engineers, Volume 12, pp. 583-594 (in Japanese).

Takase, T., Morikawa, T. 2005. Airport Choice Analysis of International Passengers Using Time-Series Disaggregate Data. Research in Transportation Economics, Volume 13, pp. 197-210.

Takebayashi, M. 2011. The runway capacity constraint and airlines' behavior: Choice of aircraft size and network design Transportation Research Part E: Logistics and Transportation Review, Volume 47, Issue 3, pp. 390-400.

Takebayashi, M. 2012. Managing the multiple airport system by coordinating short/long-haul flights. Journal of Air Transport Management, Volume 22, pp. 16-20.

Tokyo City Aviation Bureau, 2010. Chofu Airport, Last accessed on May 2010 at http://www.cab.mlit.go.jp/tcab/.

Tokyo City Aviation Bureau (TCAB), 2012. Last accessed on November 2012 at http://www.cab.mlit.go.jp/tcab/statistics/01.html.

Tokyo Metropolitan Government, 2005. City Profile. Last accessed on May 2010 at http://www.metro.tokyo.jp/ENGLISH/PROFILE/.

Tokyo Metropolitan Government, 2010. Local Ordinance on Airports Administrated by Tokyo Metropolitan Government. Last accessed on May 2010 at http://www.reiki.metro.tokyo.jp/reiki_honbun/g1011545001.html.

Tretheway, M., 2001. Alliances and Partnership Among Airports. 4th Hamburg Aviation Conference. Hamburg.

U.S. Energy Information Administration, 2010. Jet Fuel Spot Price FOB, Last accessed on May 2010 at http://tonto.eia.doe.gov/.

U.S. Government Printing Office, Federal Aviation Regulations Part 25, Last accessed on May 2010 at http://ecfr.gpoaccess.gov/.

Uemura, T., Hirai, S., 2010. Problems of airports in Japan. Koubunsha-shinsho, Japan, pp. 41-45 (in Japanese)

Uno, H., 2005. Policy agenda of life reconstruction support system for disaster sufferers. Journal of Japan Society for Natural Disaster Science, Volume 20, Issue 4, pp. 449-462 (in Japanese)

Upham, P., Raper, D., Thomas, C., McLellan, M., Lever, M., & Lieuwen, A., 2004. Environmental Capacity and European Air Transport: Stakeholder Opinion and Implications for Modelling. Journal for Air Transport Management, Volume 10, Issue 3, pp. 199-205.

Urakawa, G., Hayashi, H., Fujiwara, K., Tamura, K., 2008. Common operational picture of emergency management center, Niigata Prefecture at Niigata-ken Chuetsuoki Earthquake, 2007. Journal of Social Safety Science, Volume 10, pp. 531-541(in Japanese)

Usami, M., Akai, N., 2012. Financial performance of airport terminal companies in Japan – Harmful effects of government participation. Journal of Air Transport Management, Volume 25, pp. s 40-43.

Williams, G., Pagliari, R., 2004. A comparative analysis of the application and use of public service obligations in air transport within the EU. Transport Policy, Volume 11, Issue 1, pp. 55-66.

Yahoo Finance, 2010. USD-JPY Exchange Rate, Last accessed on May 2010 at http://stocks.finance.yahoo.co.jp/stocks/history.

Yahoo Japan Transit Map, 2010. Last accessed on May 2010 athttp://transit.map.yahoo.co.jp/.

Yai, T., Saito, T., 2002. Analysis of aircraft size changes in a domestic aviation market, Japan Society of Civil Engineering (in Japanese)

Yai, T., Hashimoto, Y., 2011. Innovation of Japanese aviation with regional jets. Seizando Publishing. Chapter 8 (in Japanese)

Yamagata Prefectural Government (YPG), 2011. The record of East Japan great disaster.

Yamauchi, H., 2000. Toward a More Liberal Sky in Japan: Deregulation and Interdependence in the Asia-Pacific Region. University of Chicago Press. NBER-EASE, Volume 8, Issue 6, pp.195-225.

Yamaguchi, K. 2007. Inter-regional air transport accessibility and macro-economic performance in Japan. Transportation Research Part E, Volume 43, Issue 3, pp. 247–258.

Yang, H., Zhang, A. 2012. Effects of high-speed rail and air transport competition on prices, profits and welfare. Transportation Research Part B: Methodological, Volume 46, Issue 10, pp. 1322-1333.

Yoshida, Y., Fujimoto, H., 2004. Japanese-airport benchmarking with the DEA and endogenous-weight TFP methods: testing the criticism of overinvestment in Japanese regional airport. Transportation Research E, Volume 40, Issue 6, pp. 533-546

Yoshitsugu, I., 2011. Staging Care Unit (SCU) at Hanamaki Airport. Nursing Technology, Volume 57, Issue 12, pp. 1068-1073 (in Japanese).

Warnock-Smith, D., Morrell, P. 2008. Air transport liberalisation and traffic growth in tourism-dependent economies: A case-history of some US-Caribbean markets. Journal of Air Transport Management, Volume 14, Issue 2, pp. 82-91.

Zhang, A., Hanaoka, S., Inamura, H., Ishikura, T. 2008. Low-cost carriers in Asia: Deregulation, regional liberalization and secondary airports. Research in Transportation Economics, Volume 24, Issue 1, pp. 36-50.

Zhang, J., Liang, X., 2011. Business ecosystem strategies of mobile network operators in the 3G era: The case of China Mobile. Telecommunication Policy, Volume 35, Issue 2, pp. 156-171.

(Intentionally Blank)

Appendix

(Intentionally Blank)

Appendix

Toulouse Business School
Management Research Centre

Université de Toulouse

1st February 2013

To whom it may concern

I hereby certify that **Mr. Nobuaki Minato** has been conducting doctoral research on air transport systems under the supervision of Professor Risako Morimoto since 2009 at the Ecole Superieure de Commerce de Toulouse (ESCT), France, and that he completed all the doctoral research modules jointly offered in Kuala Lumpur by the ESCT and UNIRAZAK in 2010.

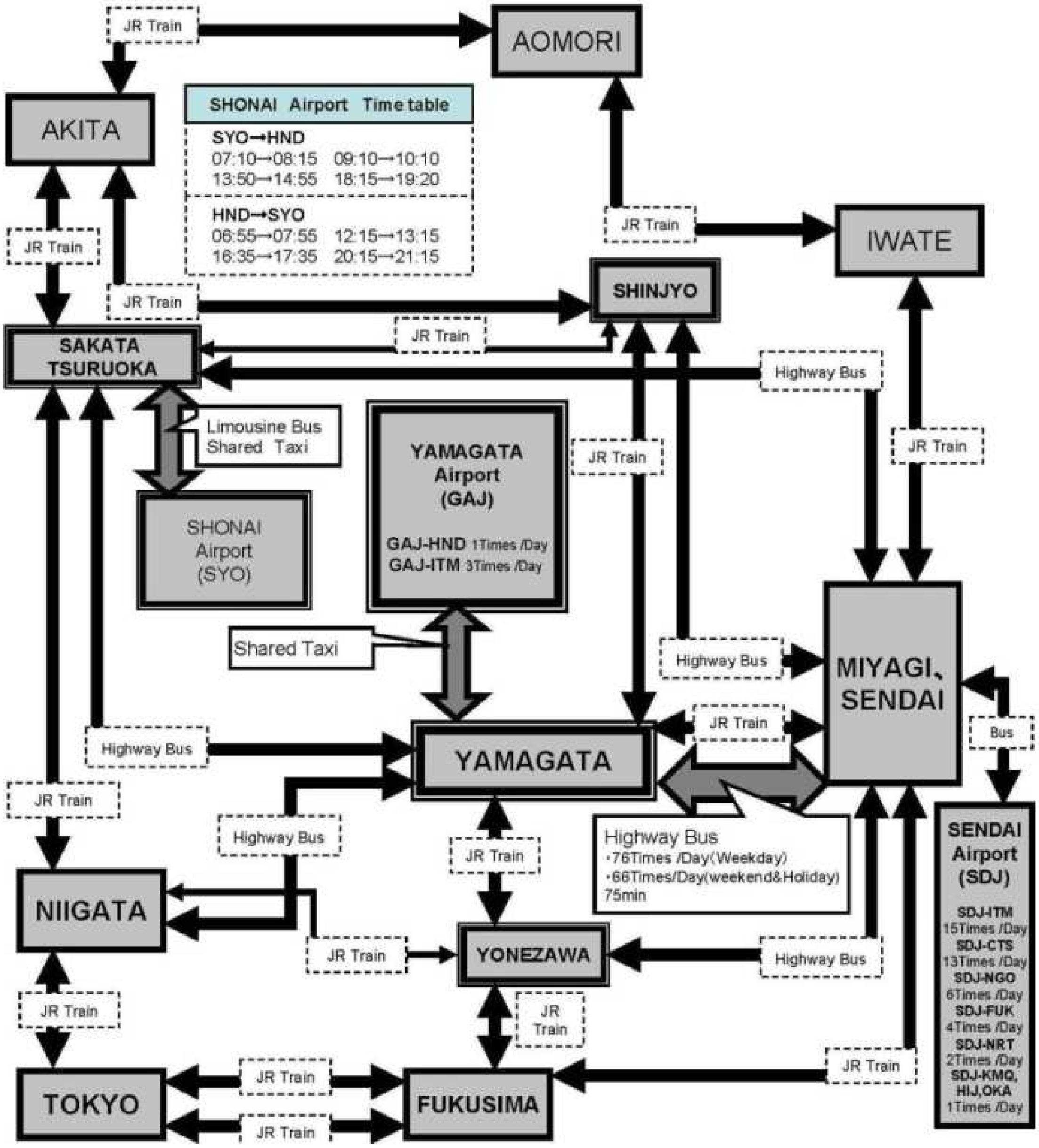
For reference, please see the thesis database at THESA, le portail des Thèses de doctorat en cours dans les Grandes Ecoles de la CGE at http://thesa.inist.fr/

Yours sincerely

Professor Dr. Jonathan Winterton
Director of International Development

Groupe ESC Toulouse, 20 Boulevard Lascrosses BP7010, 31068 TOULOUSE Cedex 7, France

Appendix 1 Doctoral Research Certification from EST Toulouse



Appendix 2 Substitute transport network diagram
(Source: Yamagata Prefectural Government)

Appendix 3 BSD-SD Conversion Matrix

			BMC Blocks								
	S: Stock Variable F: Flow Variable A: Auxiliary Variable P: Parameter		Customer Segments	Value Propositions	Channels	Customer Relations	Revenue Streams	Key Resources	Key Activities	Key Partners	Cost Structure
Name of Variables	Sign	Unit	CS	VP	CH	CR	R$	KR	KA	KP	R$
Potential Customers	S	person/month	○								
Customers	S	person/month	○								
Backlog	S	product/month				○					
Inventory	S	product/month		○					○		
Material	S	product/month						○	○		
Number of Employee	S	person/month						○			
Assets	S	$/month						○			
Free Cash Flow	S	$/month					○				○
Adoption	F	person/month	○								
Discard	F	person/month	○								
Order Rate	F	product/month				○					
Order Fulfilment Rate	F	product/month				○					
Shipment Rate	F	product/month			○						
Production Rate	F	product/month							○		
Supply Rate	F	product/month								○	
Employment Rate	F	person/month						○			

Investment	F	$/month						○			
Depreciation	F	$/month						○			
Cash In	F	$/month				○					
Cash Out	F	$/month									○
Adoption By AD	A	person/month	○								
Adoption By WOM	A	person/month	○								
Customer Order Rate	A	product/month				○					
Initial Purchase Rate	A	product/person				○					
Repeat Purchase Rate	A	product/person				○					
Desired Shipment Rate	A	product/month			○						
Required Employee	A	person/month							○		
Labor Gap	A	person/month						○			
Supply Order	A	product/month								○	
Total Cost	A	$/month									○
Operation Cost	A	$/month									○
Admin Cost	A	$/month									○
Variable Cost	A	$/month									○
Fixed Cost	A	$/month									○
Production Cost	A	$/month									○
Material Cost	A	$/month									○
Distribution Cost	A	$/month									○
Labor Cost	A	$/month									○
Revenue	A	$/month					○				
Profit	A	$/month					○				
Profit Rate	A	%					○				

Net Profit	A	$/month					○				
Net Profit Rate	A	%					○				
NPV	A	$					○				
Market Size	P	person	○								
Contact Rate	P	person/month	○								
Ad Effectiveness	P	%				○					
Product Attractiveness	P	%		○							
Initial Sales per Customers	P	product/person	○								
Average Consumption per Customer	P	product/person	○								
Delivery Time	P	month			○						
Production Time	P	month							○		
Supply Time	P	month								○	
Labor Adjustment Time	P	month								○	
Discard Rate	P	%		○							
Sales Price	P	$/product		○							
Production per Employee	P	person							○		
Initial Employees	P	person						○			
Initial Materials	P	product						○			
Initial Inventory	P	product						○			
Unit Distribution Cost	P	$/product									○
Unit Production Cost	P	$/product									○
Unit Material Cost	P	$/product									○
Unit Labor Cost	P	$/person									○

Rent	P	$/month									○
Admin Cost Rate	P	%									○
Tax Rate	P	%					○				
Discount Rate	P	%					○				
Default Rate	P	%					○				
Payment Delay	P	month					○				
Depreciation Rate	P	%									○
Investment Rate	P	%									○
Initial Investment	P	$									○