THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

POPULATION DECLINE, INFRASTRUCTURE AND SUSTAINABILITY

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DECLARATION

I certify that the thesis I have presented for examination for the MPhil/PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others.

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ABSTRACT

Japan has experienced population decline since 2010 and the situation is expected to become more severe after 2030 with forecasts indicating an expected 30% decline from 2005 to 2055. Many other developed countries such as Germany and Korea are also experiencing depopulation.

These demographic changes are expected to affect society at many levels such as labour markets decline, increased tax burden to sustain pension systems, and economic stagnation. Little is known however about the impacts of population decline on man-made physical infrastructure, such as possible deterioration of current infrastructure or increased financial burden of sustaining it. Infrastructure can be classified into 3 categories: point-type (e.g. buildings), point-network type (e.g. water supply) and network type (e.g. road). The impact of depopulation may vary according to the type of infrastructure. Previous research in this area has been limited in scope (e.g. case studies conducted in a single city focusing on a single type of infrastructure) and method (e.g. most research in the topic has been qualitative).

This thesis presents a new comprehensive study on the impacts of population decline on infrastructure in Japan, taking into account all types of infrastructure and using a quantitative approach. Data collection methods include interviews and two large scale questionnaire surveys, the first conducted with municipalities and the second, a stated preference survey, conducted with members of the public. The goal of sustainable development is relevant even in a depopulated society, and hence a sustainable development framework is applied to the analysis where social, economic, environmental and engineering impacts are investigated.

The main findings indicate that some infrastructure impacts observed and reported in depopulated areas do not seem to be related to any population decline; moreover, the preferences of citizens for infrastructure development is very similar between depopulated areas and non-depopulated areas. The results also suggest that the premises of Barro's overlapping generations model, very relevant to a discussion of intergenerational decision making and related sustainability, appear to be rejected in this context.

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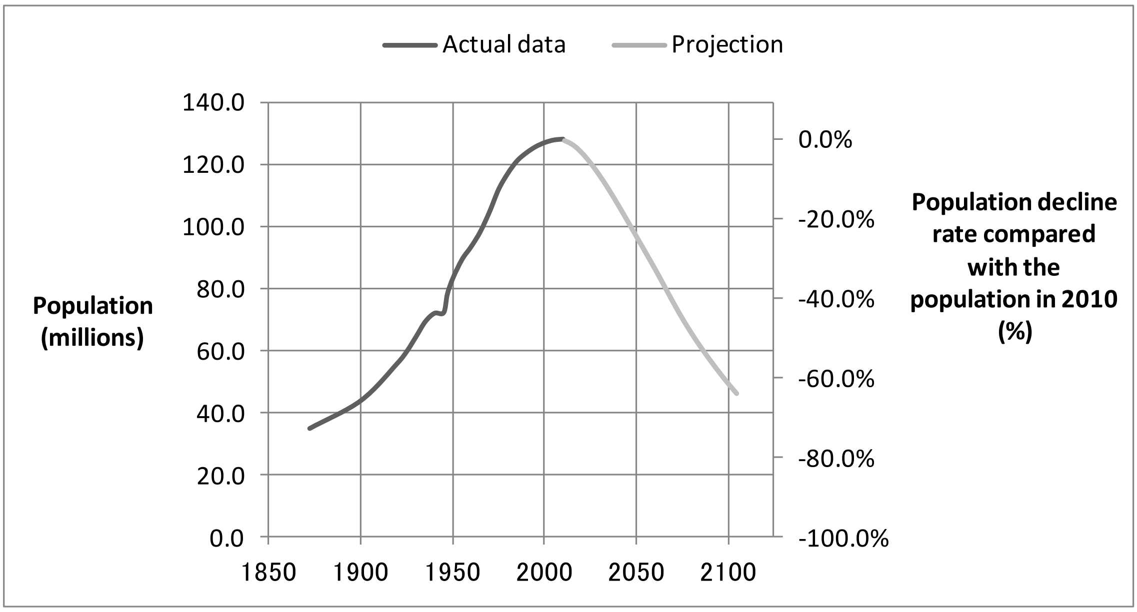
CHAPTER 1: INTRODUCTION

1.1 DEMOGRAPHIC CHANGE IN JAPAN

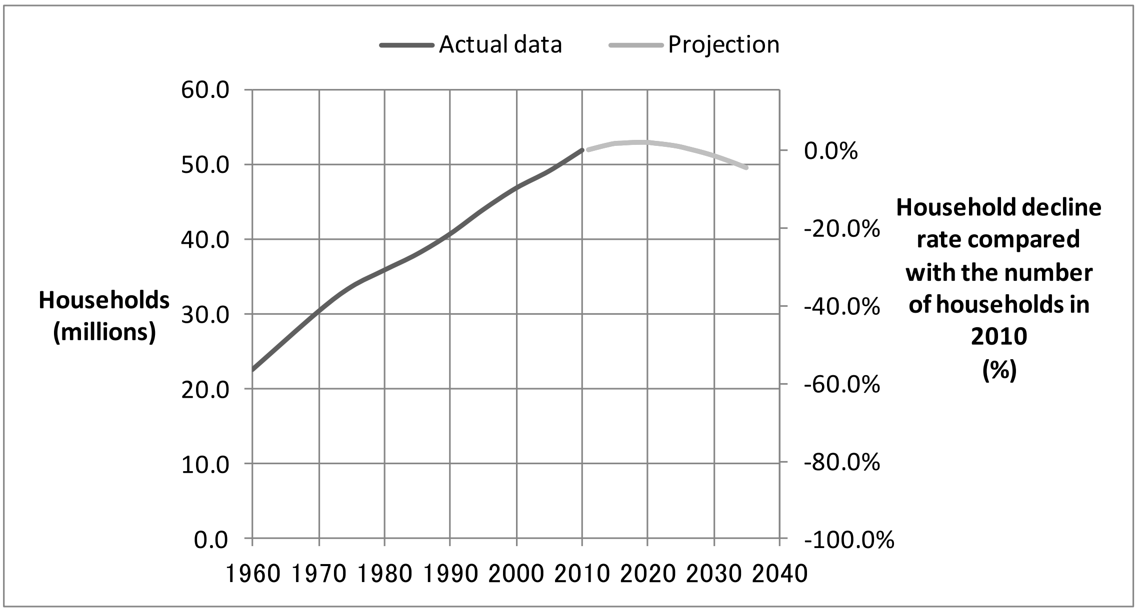
Since 2008, Japan has not only been an ageing society with low fertility rates but also a depopulating society (Senno, 2009). Official population projections indicate that population in Japan will be 8.9% lower by 2030 and 28.2% lower by 2055 than the population in 2010 (Figure 1)



Source: "Actual data" are from the National Institute of Population and Social Security Research (2014), Table 1-1, and "Projection" is from the National Institute of Population and Social Security Research (2012), Table 1-1.

Figure 1 Long-term population trend in Japan from 1920 to 2105.

In addition to population decline, the latest official forecasts suggest that the decline in the number of households in Japan will begin in 2019 (Figure 2).



Source: "Actual data" are from the National Institute of Population and Social Security Research (2014), Table 1, and "Projection" is from the National Institute of Population and Social Security Research (2013), Table 7-1.

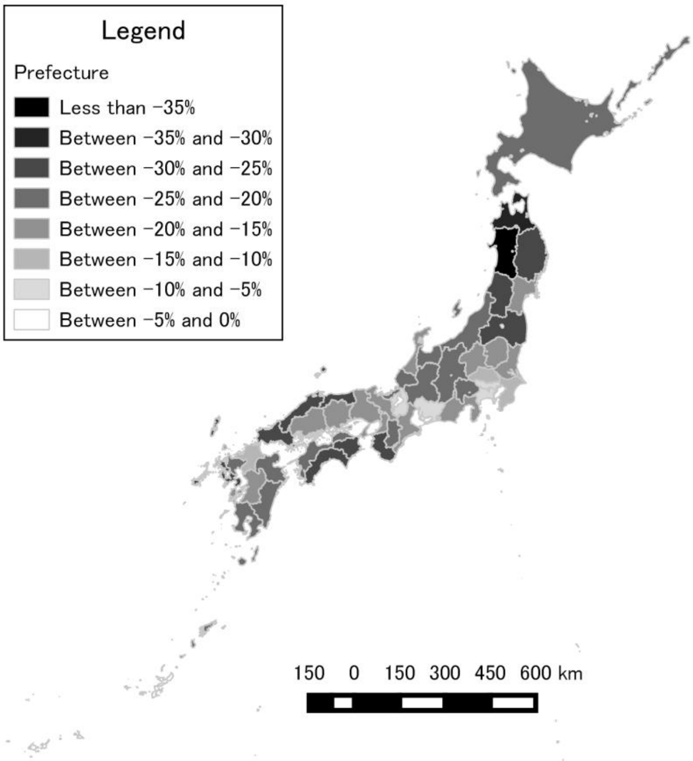
Figure 2 Long-term projection of the number of general households in Japan from 1960 to 2035.

Population decline is not a novel problem. Not just in Japan but also all over the world depopulation in rural areas is recognised as being a common and universal problem (Mckenzie, 1994). But population decline is not restricted to rural areas.

Typical causes of population decline are identified as economic transformation, suburbanisation, demographic change (e.g. falling birth rates, outmigration in rural depopulated areas), structural upheaval (collapse of a political system, unrest, resettlements) and environmental pollution (Wiechmann and Wolff, 2013).

In urban areas, industrial decline can typically cause population decline (Lötscher, Howest, and Basten, 2004). A typical case of urban population decline can be observed in Manchester in the United Kingdom (Kidd, 2006). Another well-known case of urban population decline was caused by domestic social migration from East to West Germany after its reunification (Lötscher, 2005). In these cases, and for many years, regional population declined while at the same time national population increased (Figure 4). In other words, the population decline was the result of domestic population redistribution. In such cases, national population growth allowed central governments to reallocate the benefits of the consequent national economic growth to revitalise depressed areas, bringing social migration to the areas once more.

In contrast, population decline in Japan will be a nationwide decline. This is because the main cause of population decline in Japan is natural decline owing to excessively low fertility rates that cannot sustain the population. That means that not only regional level population decline but also national level population decline is occurring (Figure 3). All regions except for the two prefectures of Tokyo (metropolitan) and Okinawa (remote islands) are expected to suffer from population decline by 2030, whereas the national population will be 10% less by 2030 than it was in 2005. At the same time, seven prefectures (black shading in Figure 3) are highly likely to suffer from serious population decline; that is more than a 20% population decline compared with the population in 2005.



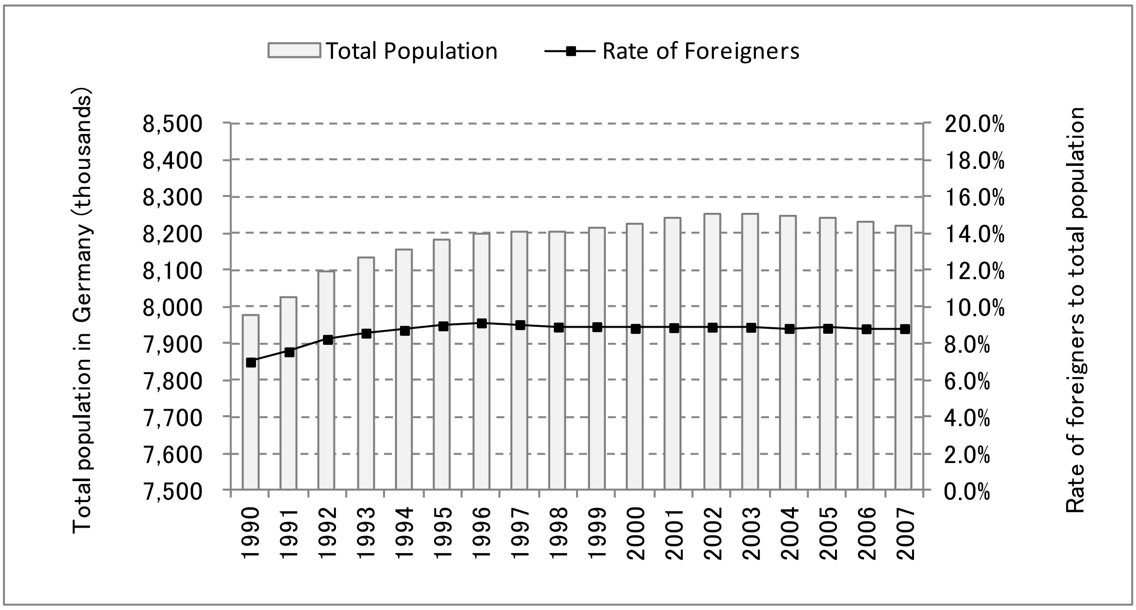
Source: Author's adaptation of data from the National Institute of Population and Social Security Research (2014), Table 1.

Figure 3 The rate of population decline in prefecture level in Japan between 2010 and 2040.

In such a situation, if a depopulating region tries to revitalise itself and to attract people from other regions, the latter regions will lose their population instead. The idea that population decline mitigates congestion problems in an area with an over-intensive population can be persuasive, but the rate of expected population decline in Japan might be such that even high population-intensive areas could be negatively affected. Based on this consideration, in a country such as Japan, domestic social migration may be unable to solve both regional population decline problems and congestion problems in highly intensive population areas.

Another general solution for population decline in the world is to accept immigrants and labour forces from abroad. The acceptance of immigrants to Japan could help to solve the future global problem of population explosion. However, there are three reasons that prevent the government of Japan from accepting immigrants at present.

First, immigrants will not easily overcome population decline in Japan. Total population in Germany, for example, has recently started to decline in spite of its acceptance of a certain number of immigrants (equal to 9% of the total population in Germany) owing to low fertility rates (Figure 4).

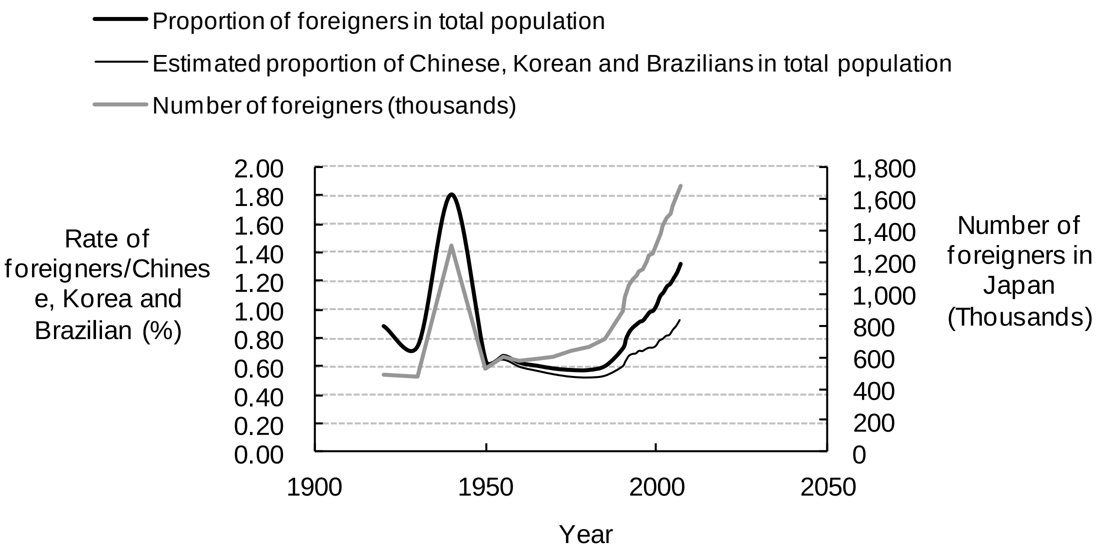


Source: Federal Statistics Office Germany (2009) GENESIS-Tabelle: Temporär, Bevölkerung: Deutschland, Stichtag, Nationalität.

Figure 4 Number of foreigners and total population in Germany from 1990 to 2007.

Some foreigners such as Koreans, Chinese and third or fourth generation Japanese-Brazilians have already lived in Japan for some time (Figure 5). The Korean and Chinese language is similar to some components of the Japanese language and these foreign nationals often have relatives in Japan.

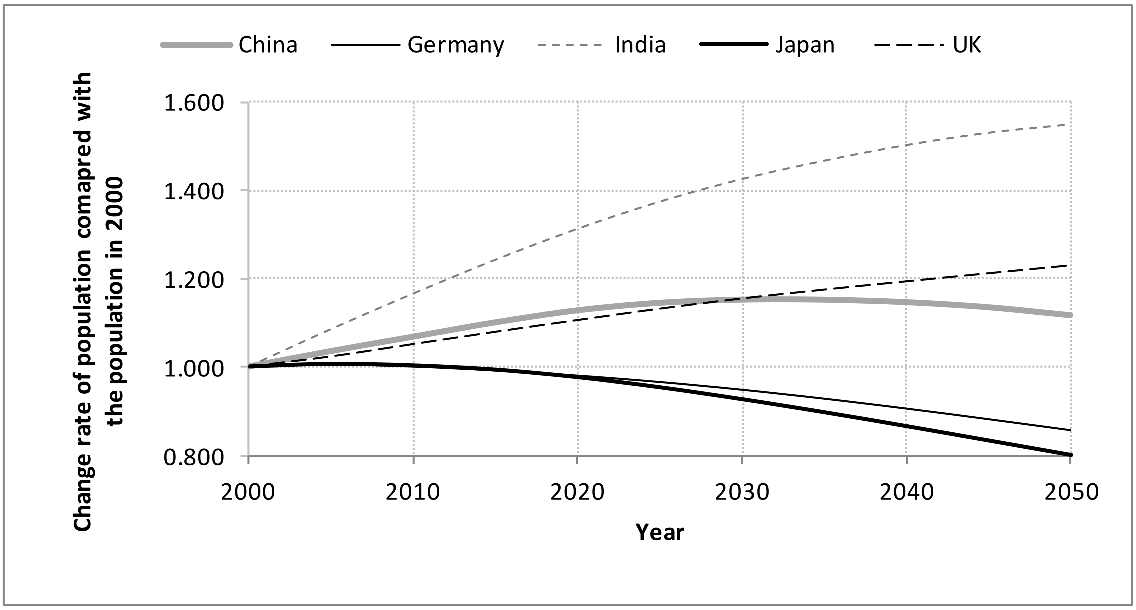
In addition, in ancient times skilled Chinese and Koreans introduced the most advanced technology of the time to Japan. Nevertheless, full citizenship including election rights is still restricted and there are some disadvantages in Korean children's education system. Therefore, it is fair to say that, at present, Japanese society is still not accustomed to cohabitating with foreign people.



Source: National Institute of Population and Social Security Research (2009), Table 5-1 and Table 10-1.

Figure 5 Number of foreigners in Japan and proportion of Chinese, Koreans and Brazilians in total population in Japan.

The second important point is that population decline will occur in other countries. Population in China is expected to increase until 2030 (Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2008) and in India until 2081 (B scenario; Population Foundation of India and Population Reference Bureau, 2007). After that, however, the population trend in both countries is expected to revert to population decline (Figure 6).



Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (2008).

Figure 6 Change rate compared with the population in 2000 in the case of the middle scenario of population projection from 2000 to 2050 in China, Germany, India, Japan and the UK.

Someone may refute the population trend in China. In fact, in terms of the "one child policy" in China, the communist party of China has introduced the relaxation of the one child policy in the third national conference of the central committee between 9th November and 12th November 2013, which allows the birth of a second child in case either of parents is an only child.

This policy relaxation apparently improves the future population decline in China, but experts do not consider it because most of provinces apart from some of major cities in China like Beijing, Tianjin, Chongqing, Jiangsu and Sichuan have already relaxed the one child policy after the middle of the 1980s (Table 1). Also, the impact of this policy relaxation is an increase in only one million births annually compared with a population of about 1.35 billion. In addition, the decline in the fertility rate in China has started before the introduction of the one child policy (Ooizumi, 2014).

Furthermore, economic growth often brings a decline in the fertility rate in Asian countries like Korea, Taiwan, Hong Kong and Singapore. China may follow this tendency as well. These suggest that the future population in China will still decline but only the speed and magnitude will be mitigated.

Table 1 Regional birth control after the middle of the 1980s in China.

Province	Urban	Rural	Conditional relaxation	Minority	Province	Urban	Rural	Conditional relaxation	Minority
Beijing	A	A	2		Hubei	A	B	2	
Tianjin	A	A	1		Hunan	A	B	2	
Hebei	A	B	2		Guangdong	A	B	2	
Shanxi	A	B	2		Guangxi	A	B	2	
Inner Mongolia	A	B	2		Hainan	A	C	2	
Liaoning	A	B	1		Chongqing	A	A	2	
Jilin	A	B	1		Sichuan	A	A	2	
Heilongjiang	A	B	2	3	Guizhou	A	B	2	
Shanghai	A	A	1		Yunnan	A	C	2	3
Jiangsu	A	A	1		Tibet	C	C	−	∞
Zhejiang	A	B	2		Shaanxi	A	B	2	
Anhui	A	B	1		Gansu	A	B	2	
Fujian	A	B	1		Qinghai	A	C	2	3
Jiangxi	A	B	2		Ningxia	A	C	2	3
Shandong	A	B	2		Xinjiang	A	C	2	3
Henan	A	B	2						

Note: A: One child policy

B: The second child is allowed in case the first child is a girl

C: The second child is allowed without any condition

1: The second child is allowed when either husband or wife is an only child.

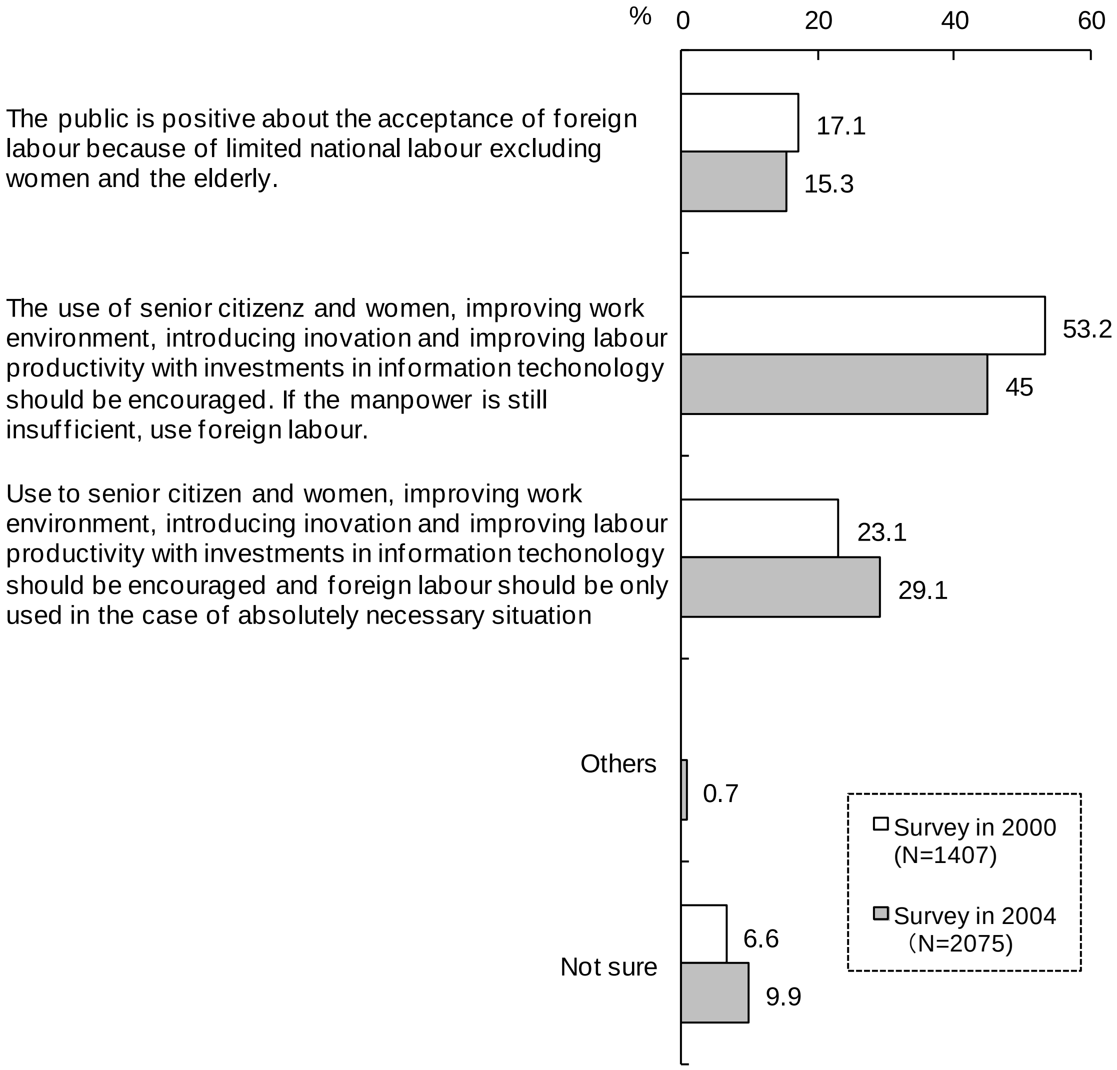
2: The second child is allowed when both husband and wife are only children.

3: The third child is allowed.

Source: Ooizumi (2014).

The population of Japan represented 1.89% of the world population in 2008 (Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2008) and acceptance of immigrants to Japan will certainly mitigate to some extent the impacts of population decline in the country until 2030 and, simultaneously, possible harmful population increase in the immigrants' countries of origin. When China and India undergo population decline, however, a 0.1% population decline in these two countries will mean a loss of more than one million people in each and no one can assume that this huge population loss will be met by immigrants from other countries. Of course, the government of China and the government of India might naturally implement demographic policies to prevent or mitigate such population decline in the future. But they are unlikely to avoid declining fertility rates resulting from economic growth, given the experiences of developed countries so far. This shows that, sooner or later, the world will have to tackle the impacts of population decline and population decline itself without depending on migrations.

The third difficulty in assuming that Japan accepts immigration now is the public's psychological resistance. At this time we cannot find any academic research or any public opinion polls that point to an acceptance of migrants to mitigate the impacts of population decline in the future depopulating Japan. Figure 7 displays the results of a rare public opinion poll in terms of accepting foreign labour forces in 2000 and 2004.



Note: The question is "Given the ageing population and forecasted population decline in Japan, what do you think about acceptance of foreign labour forces as a solution to the future insufficiency of the Japanese labour force?"

Source: Government of Japan (2004).

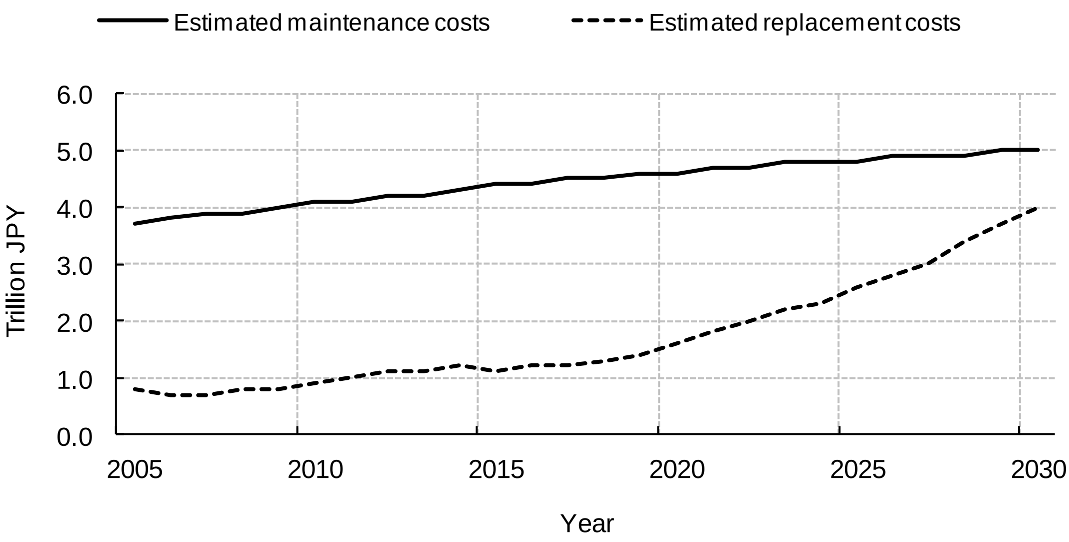
Figure 7 Current public opinion on acceptance of foreign labour force in Japan owing to ageing and declining population.

The results in both years indicate that only 15% or so agree with accepting foreign labour forces. Around half of all respondents considered it as the last resort after other measures such as utilising the elderly and women, improving labour productivity and so on. Around 25% of respondents in both surveys rejected the acceptance of a foreign labour force even if the Japanese labour force is insufficient in the future. Interestingly, from 2000 to 2004 the percentage of responses giving passive acceptance decreased by 8.2% but those rejecting the possibility increased by 6%. No similar surveys have been conducted recently, but it can be said that this result suggests that the psychological resistance to foreign labour forces in Japan still exists to a certain extent. Consequently, Japan might have to manage population decline and its impacts without considering immigrants.

1.2 Impacts of Population Decline

There are multiple impacts of population decline. A well-known impact is the increase in citizens' tax burden needed to sustain the pension system in an ageing and depopulating society. This is often discussed from the perspective of intergenerational benefit–burden transfer (Oguro and Takama, 2007). Furthermore, the lack of labour owing to population decline, shrinkage of the domestic market, and stagnation of the economy are also aspects of concern.

In terms of the material (physical) infrastructure, sustaining it in the future is already a matter of concern to the Ministry of Land, Infrastructure and Transport in Japan (2006). The maintenance costs of material infrastructure will gradually increase by more than one trillion Japanese yen by 2030. Furthermore, replacement costs of present infrastructures will be more than four times as much as they were in 2005 (Figure 8). In the same period, Japan will lose almost 10% of its population so that new construction of material infrastructure will be strongly restricted and is expected to be almost impossible. In addition, in some cases, insufficiently maintained infrastructures are highly likely to occur. This situation may cause serious problems such as those reported in the United States in the 1960s, such as falling bridges, potholes on the pavement, and so on (Choate and Walter, 1983).



Note: Roads, ports, airports, public housing, wastewater management, urban parks, flood management facilities, and coast erosion prevention facilities are considered.
Source: Ministry of Land, Infrastructure and Transport (2006) White Paper in 2005, http://www.mlit.go.jp/hakusyo/mlit/h17/hakusho/h18/html/H1038c10.html

Figure 8 Estimated maintenance costs and replacement costs of publicly owned infrastructure in Japan.

1.3 INFRASTRUCTURE AS THE SUBJECT

Infrastructures are sometimes considered to include three types: material infrastructure, personal infrastructure and institutional infrastructure (Buhr, 2007). They are also known as material infrastructure, immaterial infrastructure and institutional infrastructure (Kuckshinrichs et al., 2006). The names are slightly different, but the two typologies suggest that whole infrastructures can be categorised as: first, so-called tangible and technical infrastructures such as roads, bridges, levees, dams, buildings, water distribution networks, and so on, which can be further classified as point infrastructures, point-network infrastructures and network infrastructures (Buhr, 2007); second, human infrastructures, for example, human capital, education systems, health services, and other social services as well as legal, economic, and social systems (Kuckshinrichs et al., 2006).

Past research looking at the impacts of population decline on infrastructure from an urban/rural development perspective, have been concerned with soft infrastructures such as social capital, care of the elderly, and so forth (personal infrastructures), with the budgetary situation in the public sector (institutional infrastructures) and to some extent with material infrastructures, but did not focus in any depth on technical infrastructures (Taira, 2005).

Researchers have only slightly touched on infrastructure issues such as the frequency of public transport and merging education facilities, and their discussions do not include enough discussion on the impacts of population decline. While the three types of infrastructure are essential when we consider what will happen in a depopulating society, owing to the scarcity of previous research, the impacts of population decline on material infrastructure should be given more attention.

This focus on infrastructure can introduce a different approach to discuss shrinkage of a region. The urban/regional development approach can be considered as a vertical approach while it can be said that the infrastructure perspective is rather a horizontal approach. This is because infrastructure is the foundation of society and a common structure beyond time and place. On the other hand, urban or regional development includes not only infrastructure development, but also many factors like land use development, social development, sometime local industry development, education, culture, and other related factors in a certain area. As a result, infrastructure is just touched in the shrinking cities' discussion, but there is very few detail and comprehensive as well as numerical analysis conducted in the previous discussion. In the previous discussion, infrastructure may be regarded as something like tools for revitalizing the shrunk region, and not necessarily focused on how to manage it in the sustainable way.

Of course, other factors than infrastructure are considered when the demands for the infrastructure are discussed, and in the developing stage, the infrastructure development tends to follow the demand change of upper layers of certain areas. But how is it in a depopulating process? Can the same tendency of infrastructure development be observed? Will population decline be able to result in a decline in the amount of infrastructure service provision easily?

From the infrastructure development side, are there any policy solutions to control demographic change? Is such an order change discussion useless to find useful different policy ideas to mitigate the impacts of population decline in society in contrast to a population growth situation?

In order to answer these research questions, this study employs the horizontal approach and discussion from the infrastructure perspective on the impacts of population decline on infrastructure. In other words, infrastructure is not simply following regional development change, but infrastructure development may constrain the regional development in the process of shrinkage.

For the further discussion, chapter four will provide the history of infrastructure development as well as the administrative system of infrastructure development and management in Japan, which are expected to help readers understand the following discussion better.

1.4 Introduction of the Sustainable Development Framework

When we discuss the impacts of population decline on infrastructures we can approach it from the concept of "sustainability". The concept of sustainability has some of the merit to discuss the impacts of population decline on infrastructure.

It necessitates the continuity of the quality of society. This concept provides the baseline to what extent the infrastructure service provision should be kept in the depopulating society as a norm. It also demands the importance to take the balance of several aspects of society between the current generation and future generation. This provides the framework of evaluating the impacts of population decline on infrastructure. Also, it provides the time frame when discussing the impact occurrence and countermeasures to the impacts.

The "sustainability concept" also introduces a few ideas of how to keep the quality of society, called "strong sustainability", which is considered as "no trade off between economic gain and environmental quality [which] is acceptable" and "weak sustainability", which is considered as "environmental quality [that] can be traded against economic gain; to help make all of this easier, the environment is 'valued' in monetary terms" (Bell and Morse, 2008; p. 14). When assessing the sustainability of infrastructure development and management, this difference in two definitions of sustainability raises the level of sustainability required for infrastructure.

In most of the previous studies, only the phenomena, issues and solutions for mitigation were reported and discussed, but no common framework of discussing the impacts, expected situation of infrastructure development and management, and countermeasures for the expected situation. Against this situation, it can be considered that the concept of sustainability enables providing the discussion framework appropriately.

Further discussion of what is infrastructure sustainability will be introduced in chapter five.

1.5 IMPORTANCE OF THE ISSUES OF POPULATION DECLINE, INFRASTRUCTURE AND SUSTAINABILITY

Why is an investigation of sustainable development and management of infrastructure in the context of depopulation relevant?

Referencing typical discussions on sustainable development, two concepts—namely, "the balance between multiple aspects of objects" and "intergenerational equity" —are key, as mentioned earlier.

First, in terms of intergenerational equity, this is key because the allocation of infrastructure development costs between generations is justified by both the large initial investment and their long-term usable lives (normally 50 years or more) using debt finance. Without such an allocation, future generations can freely ride on the present generation.

The second reason for the balance between benefits and burdens comes from a cost-benefit analysis, which normally applies to decision-making in infrastructure development. Similar discussions of this point are well known as Barro's equivalent theorem (Barro, 1974; Barro, 1979) on intergenerational equity on the issue of public debts. In this type of analysis, the cost can be considered as the economic aspect and the benefits can be regarded as the social, economic, and sometimes environmental aspects. Therefore it can be said that cost-benefits analysis discusses not only the balance between costs and benefits but also discusses the balance between social, economic and environmental aspects simultaneously.

Infrastructures, of course, use natural resources in construction, operation and maintenance. Sometimes infrastructure development causes landscape destruction. Too much infrastructure or less well-managed infrastructure causes some types of pollution, such as noise, odour and so on. This and the ideas mentioned earlier naturally suggest that infrastructure development should be a significant part of sustainable development discussions. Consequently, it is fair to say that the sustainability of infrastructure development or management should be discussed even in a depopulating society, as well as in an economic growth or population growth situation. Therefore, hereafter, the idea of sustainable development or management of infrastructure will be applied in this study and the investigation of what is infrastructure sustainability, even in a depopulating society, is the core of the research undertaken.

As mentioned above, the general outline of the sustainable development of infrastructure framework in the context of population decline has already been developed. However, as we further discuss in the literature review chapter, this previous work lacks detail, and indeed a quantitative treatment of the subject could not be found. To address this gap, this thesis will introduce a comprehensive quantitative approach to investigate and explore the impact of population decline on infrastructure, from a sustainability framework.

1.6 JAPAN AS AN ADVANCED COUNTRY IN POPULATION DECLINE

The thesis is based on original field studies in Japan. Japan was selected as a case study for the following reasons. First, there are very few studies that primarily investigate the impacts of population decline on infrastructures and most previous literature has focused on the United States or Germany, which has experienced serious population decline and a shrinking cities phenomenon after reunification, whereas Japan has only been a depopulating society since 2008. Therefore, the research results for Japan are expected to add much unique knowledge to the discussion of this topic.

Second, Germany is a continental country and a part of the European Union. This means that although the population in Germany is expected to decline, the population in other countries surrounding Germany may still grow, so Germany has to keep developing. For example, surface land transport such as roads and railways will be needed to encourage economic activities in other countries. In comparison, Japan is surrounded by the sea and is a closed model in terms of surface land transport and other material infrastructures, except for ports and airports. In addition, Japan does not accept immigrants so that Japan is also a closed model from a demographic perspective.

Accordingly, the research in Japan will help to conduct a comparative study between a closed model, the Japanese case, and an open model, the German case, and such a study will help to clarify the effects of the differences between them.

Third, Japan suffers many earthquakes and typhoons; therefore it has many facilities for preventing disasters. On the other hand, Germany is not often hit by serious disasters. This means that the Japanese data will be able to add to knowledge of the impacts of population decline on anti-disaster facilities. Climate change may increase the frequency of heavy rains and storms across the world. In addition, some other countries—for example China—also suffer from big earthquakes. Japanese research results will be able to help inform the management of their anti-disaster facilities since they also face population decline in the future.

Hence, Japan is arguably a key and interesting case study for research on the impacts of depopulation on infrastructure. It is hoped that the results from our study in Japan will be instrumental when investigating similar situations in countries such as Germany, Korea, certain areas in the United States in the near future, and China in the future.

1.7 AIM AND OBJECTIVES

The aim of this thesis is to conduct a comprehensive quantitative analysis of the impacts of population decline on infrastructure development and management with Japan as a case study.

Within this context, we discuss the meaning of sustainability of infrastructure development and management within a depopulating society. We consider the differences between infrastructure types based on the conceptual framework of sustainability/sustainable development. In particular, considering that Japan is still in the early stages of population decline, the research will investigate what magnitude of population decline is expected to significantly have an impact on material infrastructures, and what types of infrastructures are most affected by population decline. In order to undertake a comprehensive assessment of sustainable infrastructure development and management in the face of population decline, the thesis will investigate impacts from the viewpoints of both infrastructure managers and infrastructure users. We discuss policy implications of such impacts and identify further research tasks. The research results will enable us to discuss and develop appropriate policies for decision-makers to cope with declining population impacts on infrastructure and are expected to become a benchmark for future researchers. The results are also expected to be potentially applicable to other countries facing depopulation such as Germany, Korea, and even China after 2030.

1.8 CONTRIBUTION TO KNOWLEDGE

At present, little is known about the impacts of population decline on man-made physical infrastructure, such as possible deterioration of current infrastructure or increased financial burden of sustaining it. This thesis is one of very few existing studies that investigate the impact of population decline on infrastructure development and management. Previous research in this area has been limited in scope (e.g. case studies conducted in a single city focusing on a single type of infrastructure) and method (e.g. most research in the topic has been qualitative). In contrast, this thesis presents a comprehensive analysis of the subject, taking into account all types of infrastructure and using a quantitative approach. For the first time, large scale surveys were conducted with both service providers (infrastructure managers) and service users (residents) and the data is analysed using logistic regression models. While previous studies have focused mostly on countries such as Germany that has experienced serious population decline and shrinking cities, not much is known about impacts in Japan, the focus of this thesis, where depopulation is a very recent phenomenon. Finally, most previous work lacks a conceptual framework for analysis. This thesis proposes the use of a sustainable development framework where social, economic, environmental and engineering impacts are investigated in tandem.

1.9 STRUCTURE

The structure of the thesis is as follows. This chapter (Chapter one) explains the background, aim and structure of the thesis. Chapter two introduces the conceptual framework and methodology employed. A general description of the methodologies used will be introduced in chapter two, but detailed discussions of each method will be contained within each of the following analysis chapters.

Chapter three and five are preliminary chapters for the following discussion. Chapter three shows actual population changes in not only depopulating areas, but also in population growing areas to share the overall picture of population change in Japan. Chapter four provides the history of infrastructure development in Japan, the governmental administrative system for infrastructure development and financing policy for infrastructure development and management. This can provide the basic policy knowledge of the following discussion. Chapter five introduces the various discussions on sustainability; in particular, what is sustainable infrastructure development and management. This chapter can frame the following discussion.

The main five research chapters follow these preliminary discussion chapters. Chapter six contains the literature review on the impacts of population decline on infrastructure development and management. Chapter seven, the first analysis chapter, presents the results of in-depth interviews conducted with infrastructure managers in selected municipalities in Japan facing long-term population decline. Using data from a large quantitative survey of infrastructure managers in depopulating municipalities in Japan and binary logit regression analysis, Chapter eight investigates the relationship between infrastructure impacts and their potential causal factors to estimate the risk of impact occurrence in depopulating areas. Chapter nine uses choice experiments to analyse the relative importance of key aspects of infrastructure sustainability—namely, “society”, “engineering”, “environment”, “economy” and “timing of development and management” —from the perspective of infrastructure users, using a large sample of Japanese residents. The rationality of intergenerational or long-term intertemporal decision-making by citizens is also discussed.

Discussion and analysis is conducted in Chapter 10, which reflects on the results of various analyses presented in the thesis and offers a discussion of the effects of population decline on society, with particular reference to infrastructure development and on the type of countermeasures that can be applied.

The last chapter concludes the thesis and discusses further research needs in order to solve the identified gaps in knowledge.

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Chapter 2: Methodology

2.1 INTRODUCTION

This chapter briefly describes the research framework used, the research methods employed, and the reasons why they were selected. We focus on a summary overview of the methods, their selection process and conceptual framework. A more detailed description of each method is contained within the chapter where each particular method is used.

First we introduce the research framework. The overall aim of this thesis is to identify what the sustainability of infrastructure development and management is, even in a depopulating society, and specifically in Japan. This naturally first requires an explanation of what sustainable infrastructure development and management means.

After the research framework, the methods of data collection and the analytical analysis methods are introduced. In terms of data collection, we were unable to find sufficient public statistics data on this topic even in Japan, where data is plentiful across all social research sectors. This is because, when this study started, there was no definition of what the real impacts of population decline are on infrastructure management. Furthermore, in many cases, the impacts are subjective matters from the perspective of the observer. Of course, the researchers should ideally provide appropriate definitions for the impacts of population decline and also give proper criteria for the impacts of population decline on infrastructure development and management. At the beginning of this research, however, it was considered too difficult to establish those clear definitions and criteria.

Based on these difficulties, this study adopted the strategy of discovering what has happened through empirical observation, using the same standard procedure all over Japan. The results of assessment using the same standard will help define an appropriate definition of the impacts of population decline. Specifically, we used surveys of both municipalities' officers and infrastructure users to collect data on the perceived current situation of infrastructure development and management and their usability. In addition to the survey data, secondary data such as demographic data, the amount of infrastructure, geographical situation etc. have also been collected and are used in the subsequent statistical analysis.

As noted before, we are interested in the relationship between sustainable infrastructure development and demographic change, the variety of infrastructure types, what the real impacts of population decline are, and so on. In discussing these relationships, this research has focused on the probability of impacts of population decline on infrastructure management. In other words, if the impacts do not occur often, they are not serious, but if the impacts occur frequently, they are seen as being problematic. Binary logistic regression analysis was used to analyse the survey data collected on this topic from providers of the infrastructure, i.e. municipality officers. In turn, survey-based choice experiment methods were used to look at infrastructure users' preferences between multiple aspects of sustainability, and conditional logit regression analysis was used to analyse these choice data. In the following subsections, theoretical aspects of these methods are introduced, but the details of each method will be presented and discussed in each analysis chapter, as mentioned above.

2.2 Research framework

This research is divided into two parts, preliminary research and main research. In terms of preliminary research, before starting the main discussion, the current situation of population change in Japan, the history of infrastructure management in Japan and the concept of sustainability are introduced as the three main perspectives of this research. They are necessary to understand the ensuing researches conducted in Japan.

On the other hand, the main research is conducted from the perspective of both infrastructure managers and the infrastructure-users. This is because this research pursues a comprehensive research on the sustainable infrastructure development and management in a depopulating society, and the most emphasized point of this research is to provide an overview of all the issues.

Of course, the other reason is that the development and management of infrastructure is conducted by infrastructure managers. The impacts on the development and management of infrastructure can only be obtained from infrastructure managers. On the other hand, a key discussion point of infrastructure development and management from the point of view of sustainability is the balance between service provision and the burden on users. In order to collect opinions on this balance, both currently and in the future, research on the users' opinion is also necessary.

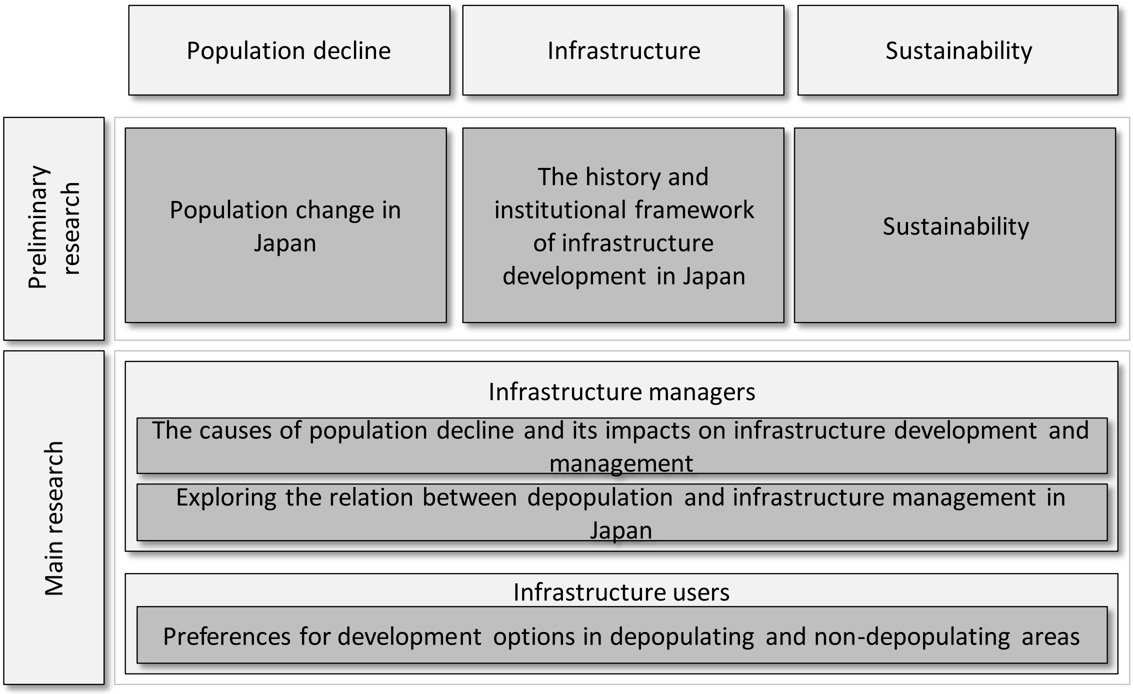

Figure 9 Framework of this research.

2.3 OBJECTIVE INFRASTRUCTURE

Any type of infrastructure managed by the public sector should be surveyed (Table 2) in this research. The types of infrastructure were categorised as point-type, point-network-type and network-type infrastructures (Buhr 2007; Table 1). The detail types of infrastructures in each category are also shown in Table 2.

Table 2 Types of objective infrastructure systems

Type	Category	Examples
Point	Education	Schools
	Housing	Public housing, dwellings
	Life support	Solid waste management, urban parks, hospitals, social care facilities, natural parks, social education facilities
	Administrative public office buildings	Administrative public office buildings
Point-network	Water and waste water	Drinking water supply, industrial water supply, waste water management
	Transport	Railways, underground systems, light-rail transit, ports, airports, buses
	Disaster management	Anti-flood afforestation, coastal management, flood control, landslide prevention
Network	Road	Roads, streets

Source: Buhr 2007; Table1.

2.4 DEFINITION OF IMPACTS

As mentioned above, giving appropriate definitions of the impacts of population decline on infrastructure management at the beginning of the study was difficult. However, in order to create a common foundation for the following discussion, it could be considered useful to provide an organized chart of the considerable potential impacts of population decline on infrastructure management, using the framework of sustainable infrastructure development as well as the steps of impact occurrence such as causes–impacts–influence, as shown in the following Figure 10 .

From the social and environmental aspects, population decline may result in direct impacts, but from the engineering and economic aspects, not only population decline but also other specific factors such as infrastructure ageing, decline in the number of engineers and financial constraints may be considered to be the triggers of impact occurrence. In addition, impacts usually arise from a change of situation for infrastructures or infrastructure users, and those impacts influence human lives. One of the difficulties of this study concerns this point. Namely, it is difficult to position the phenomenon discussed in this study in the diagram in some cases because the actual phenomena are very complicated and it is not easy to identify or distinguish between impacts and influences. This study is almost the first study on this topic; therefore, in the following analysis, those differences cannot be considered sufficiently, but in the next step they should be distinguished appropriately.

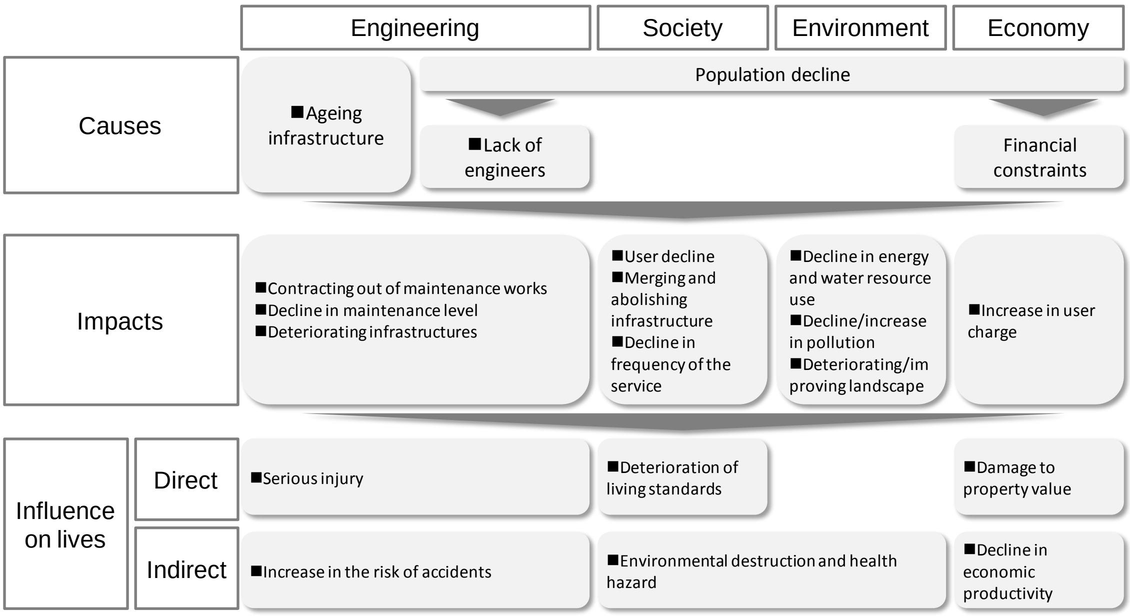

Figure 10 Classification of the causes and impacts of population decline on infrastructures.

2.5 Data collection methods

This study uses a literature review, interviews, quantitative surveys and secondary data analysis for collecting data. How the data were collected is explained in the following subsections.

2.5.1 Literature review

A literature review is conducted for not only the literature review chapter, but also for other chapters. Literature that has been collected will be introduced in each chapter and shown in the reference sections of each chapter.

To collect the literature, the National Diet Library catalogue in Japan, the Library catalogue at the London School of Economics and Political Science, Google Scholar and Google were used.

When the literature survey was conducted, typical keywords such as “population decline”, “depopulation”, “demographic change”, “out migration” and so on were used for population decline, along with, for example, “infrastructure”, “road”, “water”, “public building”, “urban infrastructure”, “rural infrastructure” and the names of types of infrastructure, although the words “urban shrinkage”, “shrinking cities” and the words which represent urban issues were not used because this study has focused on the infrastructure rather than urban and rural development themselves.

For analysing the collected literature, the framework of sustainable development as mentioned above was applied. As is well known, the framework of sustainable development includes the idea of balance between multiple aspects and intergenerational equity. The impacts on multiple aspects of infrastructure development and management and the issue of intergenerational equity were, therefore, discussed. In addition, the geographical scope, cause of population decline, extent of population decline and type of infrastructure were also considered.

2.5.2 INTERVIEWS

In this study, three face-to-face expert interviews using a semi-structured questionnaire were conducted in order to discover the actual and current situation of infrastructure management in depopulating municipalities in Japan. As shown in Table 3, there are several types of interview.

Also, supplementary interviews for Chapter 4 and Chapter 10 were conducted by telephone as well as with face-to-face expert interviews. This is because the written published materials from the government sector are often difficult to understand and needed to be clarified, and it also enabled us /the researcher(s) to confirm the background situation and aims of policies.

Table 3 List of forms of interviews and the method adopted in this study

Forms of interviews			Structured	Semi-structured	Unstructured/ in-depth interviews
Standardized	Interviewer-administered questionnaires				
Non-standardized	One to one	Face-to-face interviews		Chapter 7	Chapter 4
		Telephone interview			Chapter 4, Chapter 10
		Internet and intranet-mediated (electronic) interviews			
	One to many (focus groups)	Group interviews			
		Internet and intranet-mediated (electronic) interviews			

Source: Based on Saunders et al. (2009), 320–321.

2.5.3 Quantitative survey

Two types of quantitative surveys were conducted. One was a survey of infrastructure managers in depopulating municipalities between 1975 and 2000 by postal mail; the other was an Internet-based survey of citizens in both depopulating and non-depopulating municipalities in order to conduct a comparison study.

2.5.4 Secondary data

For quantitative analysis, this study has used several Japanese statistics. Those data were used as explanatory variables in the following numerical analysis. The exact data that were used in the following chapters will be introduced in each chapter, but here only main data sources are given for each data category.

Table 4 Data sets and sources in this study

Data	Source
Demographic data	Ministry of Internal Affairs and Communications (2011)
Geographical data	Ministry of Land, Infrastructure, Transport and Tourism (2010) for National Land Numerical Information (slope and municipality boundary data)
Financial data in municipalities	Ministry of Internal Affairs and Communications (1970–2012)
Amount of infrastructure	Ministry of Internal Affairs and Communications, the Statistics Bureau, and the Director-General for Policy Planning (every year)

2.6 ANALYTICAL METHODS

2.6.1 BINARY LOGISTIC REGRESSION ANALYSIS

What type of analytical model should be used depends on the type of data collected in the study. A standard method for how to measure the impacts of population decline on infrastructure management has not yet been established. To date, only quantitative and comprehensive research has been conducted. Hence, this study collected the data from a postal survey as explained in the previous subsection.

The data type used in the questionnaire survey on the impacts of population decline on infrastructure management is discrete binary data. The purpose of the analysis is to discuss what types of factors, such as population decline, ageing, pattern of population decline, geographical pattern, and amount of infrastructure and policy reforms are related to the results of the impacts of population decline. For analysing this relationship, regression analysis – in particular, this time, logistic regression analysis – is generally applied because dependent variables are discrete and binary data.

The basic formula of the logistic model is as follows (Hosmer and Lemeshow 2000; pp. 4–6.). When Y denotes the outcome variable and x denotes a value of independent variable, the quantity E(Y|x) is the conditional mean and reads 'the expected value of Y, given the value x'. When we can assume linear regression, it can be expressed as follows:

$$E(Y|x)=\beta_0+\beta_1 x \quad (2.1)$$

For analysing the dichotomous outcome variables, Cox and Snell (1989) proposed using logistic distribution and transform $E(Y|x)=\pi(x)$, which is called logit transformation, as follows:

$$\pi(x) = \frac{e^{\beta_0+\beta_1 x}}{1+e^{\beta_0+\beta_1 x}} \quad (2.2)$$

In fact, the following formula will be used for the estimation:

$$g(x) = \left[\frac{\pi(x)}{1-\pi(x)}\right] = \beta_0 + \beta_1 x \quad (2.3)$$

For the logistic regression analysis, the maximum likelihood estimation method, rather than the linear square estimation method, is applied. Accordingly, we cannot use any Pearson Chi-square statistic. Therefore, the Nagelkerke R square (Nagelkerke 1991) could be used as the indicator for the appraisal of the fitness of the model. This Nagelkerke R square is similar to the adjusted coefficient of determination for a multiple linear regression model, and thus it is often used for assessing the fitness of the binary logistic regression model.

$$\bar{R}^2_{\text{Nagelkerke}} = \frac{1-\left\{\frac{L(0)}{L(\hat{\beta})}\right\}^{\frac{2}{n}}}{1-\{L(0)\}^{\frac{2}{n}}} \quad (2.4)$$

2.6.2 CHOICE MODELLING

As noted above, this study applied choice modelling to analyse the balance between multiple aspects of infrastructure sustainability. Choice modelling can be used to analyse the following four points in particular (Bateman et al. 2002):

1. Which attributes are significant determinants of the values people place on non-market goods;

2. The implied ranking of these attributes amongst the relevant population(s) (for example, in planning national parks, how the provision of way marked trails is ranked relative to protecting wildlife);
3. The value of changing more than one of the attributes at once (for example, if a management plan results in a given increase in wildlife protection but a reduction in recreation access);
4. As an extension of the above, the total economic value of a resource or good.

In choice modelling, several techniques are developed such as choice experiments, contingent ranking, contingent rating and paired comparisons. However, from the standpoint of consistency in the estimation of welfare, a choice experiment is preferable. Therefore, this study employs choice experiments.

In our choice experiments, which are described in detail in Chapter 6, respondents were asked to choose their preferred infrastructure profile from choice cards containing three such profiles. These triplet choice sets were presented several times to the respondents.

Choice experiment has its roots in Lancaster's characteristic theory of value (Lancaster 1966), random utility theory, and in experimental design (Hanley et al. 1998). For the analysis, the conditional logistic regression model was applied. The basic formula is as follows:

$$p(\text{choose } g) = \frac{\exp(\beta' X_{ig})}{\sum \exp(\beta' X_{ij})} \tag{2.5}$$

where X means socio-economic variables as attributes and β is parameter vectors.

The estimation of the above formula is run as a multinomial conditional logit regression model.

2.6.3 Spatial analysis

In order to visualize the relationship between the geographical constraints and population distribution in depopulating areas, Geographical Information System software was used. This time, however, no sophisticated spatial analyses were conducted. Only visualization was conducted to help readers understand the situation in Japan.

In addition, overlaying is used for comparison between demographic change and infrastructure network distribution in Chapter 10.

2.6.4 Other analytical methods

This study also uses other types of analytical methods such as radar chart, simple simulation and so on. These analytical methods are not specific and are very common for analysing numeric data sets. There is no explanation given about them here, but detailed explanations will be provided in the following analytical chapters.

2.7 Software used in this study

This study has used SPSS, Microsoft EXCEL and R for data manipulation and Quantam GIS (QGIS) for handling GIS data. R and QGIS are open-source software programs.

2.8 Summary

It is not the aim of this study to develop new methods to analyse the phenomenon of the impacts of population decline on sustainable infrastructure development and management. Therefore, only well-known existing quantitative and qualitative methods are used for the data collection and analysis. On the other hand, such methods are applied to new data and to a scarcely studied topic in order to discover the real impacts of population decline on sustainable infrastructure development and management.

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CHAPTER 3: POPULATION CHANGE IN JAPAN

3.1. Introduction

Before starting the main discussion of the impact of population decline on infrastructure, this chapter provides the current situation of population change in Japan. This is because the Japanese population has been declining since 2008 (Statistics Bureau, 2013), but the local population change is more complex than that at national level, which should affect the use and management of infrastructure by municipalities.

The statistics in each local government can be used to confirm the difference in population change according to the geographical resolution. Specifically, national level, prefectural level, municipality level, and mesh level data is available in Japan for the discussion. It is noted that the mesh is identified by using the latitude and longitude and is almost the same size as other mesh in the same resolution in order to be used for the statistics. The Statistics Bureau of Japan provides national census data and terrain data in the ‘regional mesh’.

The aim of this chapter is to introduce an overview of population change between 1990 and 2010. For the overview discussion, while this thesis focuses on the population decline, the following section also includes cities with stable population and growing population. .

The reason why this period has been selected is that the same period is used in the context of the shrinking cities discussion (Wiechmann and Wolff, 2013). The start year affects the discussion results of population change, and accordingly some rule is necessary to decide the period. This time, to help the readers to compare the Japanese population change with the population change abroad, in particular, in Europe, the period has been determined as twenty years.

In section two, the methodology is introduced. The third section provides the graphs, tables and maps on population change in each resolution. In the fourth section, the tendency of population change is discussed.

3.2. METHODOLOGY

3.2.1 RESEARCH FRAMEWORK

To describe population change in Japan, four layers of population change can be discussed. The national level, prefectural level, and municipality level of population change between 1990 and 2010 are examined, while, because of mesh data's limitations, the mesh level of population decline between 2005 and 2010 is examined.

Furthermore, the municipality level and following mesh level populations are discussed in terms of population change, namely, declining, stable, and growing, and also by categories of size of population, namely, less than 10,000, between 10,000 and 50,000, and more than 50,000.

For the mesh level, one municipality is selected from nine cells, each categorized by both population size and tendency of population. This time, only one municipality is selected in each, but the conditions for the selection cover all categories. Therefore, nine samples can be considered as representative of current Japanese population change.

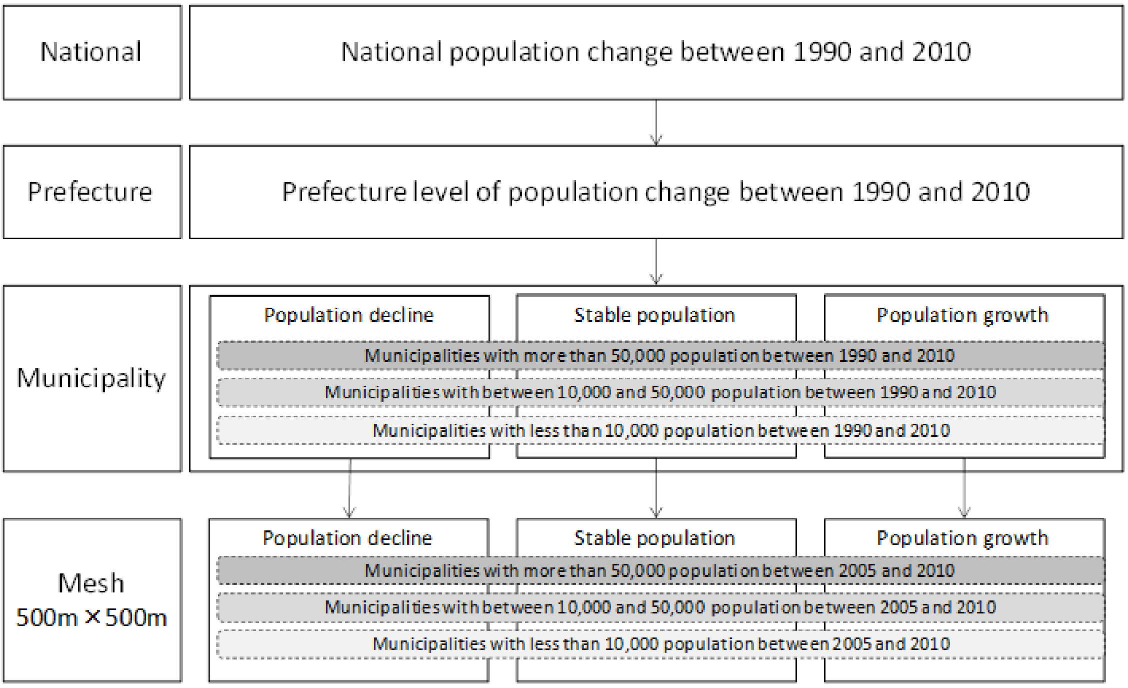


Figure 11 Research framework on population change

3.2.2 Spatial analysis

For the mesh level, overlaying population data and other geographical data like terrain, railway, public office, boundary of a densely inhabited district is conducted as a simple spatial analysis.

3.2.3 Data

To show the population change in each level, the following data are used (Table 5). Basically, various resolutions of national census data are used respectively. In addition to the national census data, National Land Numerical Information Data are used for the mesh data analysis. All these data are public data and can be downloaded from the website.

Table 5 Data set

Category	Data	Source
National	Population in 1990, 1995, 2000, 2005, and 2010.	Ministry of Internal Affairs and Communications (2013), Population Census and Population Estimates.
Prefectural	Population in 2010.	Ministry of Internal Affairs and Communications (2011), National Census of Japan.
	Population in 1990, 1995, 2005.	Ministry of Internal Affairs and Communications (2013), Population Census and Population Estimates.
Municipality	Population in 1990, 1995, 2000, 2005, and 2010.	Ministry of Internal Affairs and Communications (2011), National Census of Japan.
Mesh level	Population 2005 and 2010.	Ministry of Internal Affairs (2012), Regional Mesh Data of National Census of Japan.
	City Areas (surface)	Ministry of Land, Infrastructure, Transport and Tourism (2014) National Land Numerical Information Data
	Densely Inhabited District (surface)	
	Elevation	
	Medical Organization (point)	
	Local Government Office, etc. and Public Meeting Facility (point)	
	Railways (line)	
	Bus route (line)	

3.2.4 Definition of the City

In the following sections, the word 'city' may be used frequently, but the definition of 'city' in Japan is different from that in Europe. The differences between Japan and Europe, in particular the definition in the COST Action, are introduced in Table 6. A main difference is the size of population. This difference is about ten times as much. In addition, the European definition uses the condition of area-based population density, but the Japanese definition only uses the concentration of population in the central business district. These differences might lead to a completely different picture of the population change in Japan and that in Europe.

The similar concept of focusing on density of population is introduced instead of 'city' in Japan because the definition of 'city' doesn't include the density idea, and it is difficult to discuss urban population change in the municipalities. The concept is called 'densely inhabited district' (DID).

According to the Statistics Bureau of Japan (Statistics Bureau, 1996):

> Densely Inhabited District is designated in units of census basic unit block, and census enumeration district if there are several census enumeration districts in a census basic unit block (hereinafter referred to as 'basic unit blocks, etc.') and should meet the following criteria, in principle:
>
> 1) A district containing basic unit blocks, etc. with a population density of 4,000 or more per square kilometre, such districts being adjacent to each other in a municipality;
>
> 2) A district consisting of the above adjacent basic unit blocks, etc. whose population is 5,000 or more at the time of the Population Census of Japan.
>
> With the idea that Densely Inhabited Districts represent urban areas, a basic unit block etc. which has educational, cultural, and recreational facilities (e.g. schools, laboratories, shrines, temples, athletic fields), industrial facilities (e.g. factories, warehouses, business offices), and communal and social welfare facilities (e.g. public

offices, hospitals, sanatoriums), and which is adjacent to the other basic unit blocks, etc. mentioned under criteria (1), is also regarded as a district that meets the criteria 1). In this regard, however, population is concentrated in the remaining part excluding the area occupied by those facilities, or those facilities occupy more than half of the area of the whole district

In this way, DID is often used for discussing urban population change in statistics and from a spatial analysis perspective, and this study, therefore, introduces this concept as well.

Table 6 Different definition of 'city' between COST Action and Japanese legal system

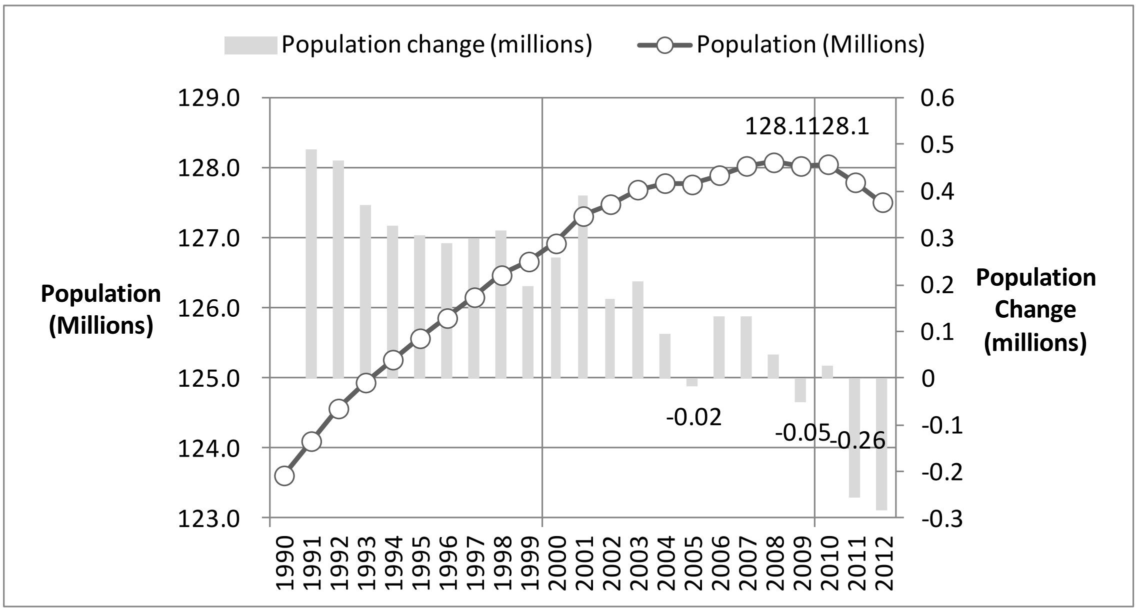
	COST Action	Local Autonomy Law, Article 8.
Population size	Total population in 2010 in the municipality is more than 5,000 inhabitants	In principal, the population is more than 50,000
Density of population	Density of the population living in densely populated parts with more than 1000 inhabitants per km2 is more than 50%	Number of households in the central business district is more than 60% of all households. The population engaging in urban businesses, such as commercial and manufacturing, is more than 60% of total population
Land use	Share of urban area (artificial surface) within the municipality is more than 5%	N.A.
Others	N.A.	Other conditions decided by the prefectural ordinance

Source: Wiechmann and Wolff (2013) and author's research results.

3.3. RESULTS

3.3.1 NATIONAL LEVEL OF DEMOGRAPHIC CHANGE

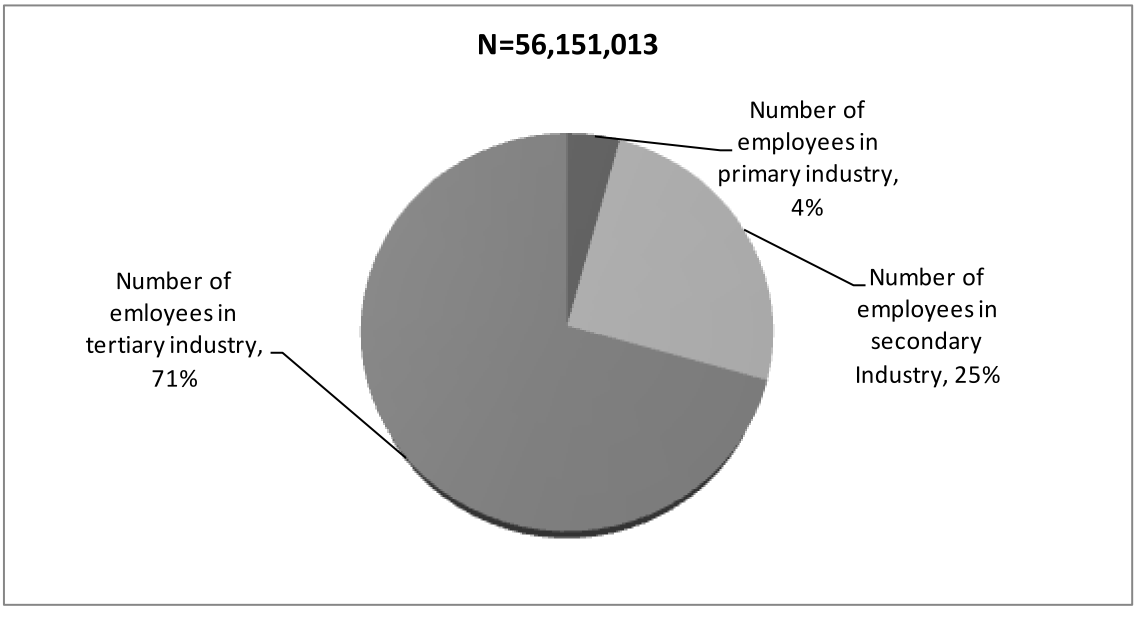
The national level of the population in Japan increased until 2008 when it peaked. Since 2010, the population has been rapidly declining. In 2011, the population declined by 260,000 million. Thus, it can be said that Japan has obviously been in an era of depopulation since 2010.



Source: Ministry of Internal Affairs and Communications (2013), Population Census and Population Estimates.

Figure 12 National population between 1990 and 2012 in Japan

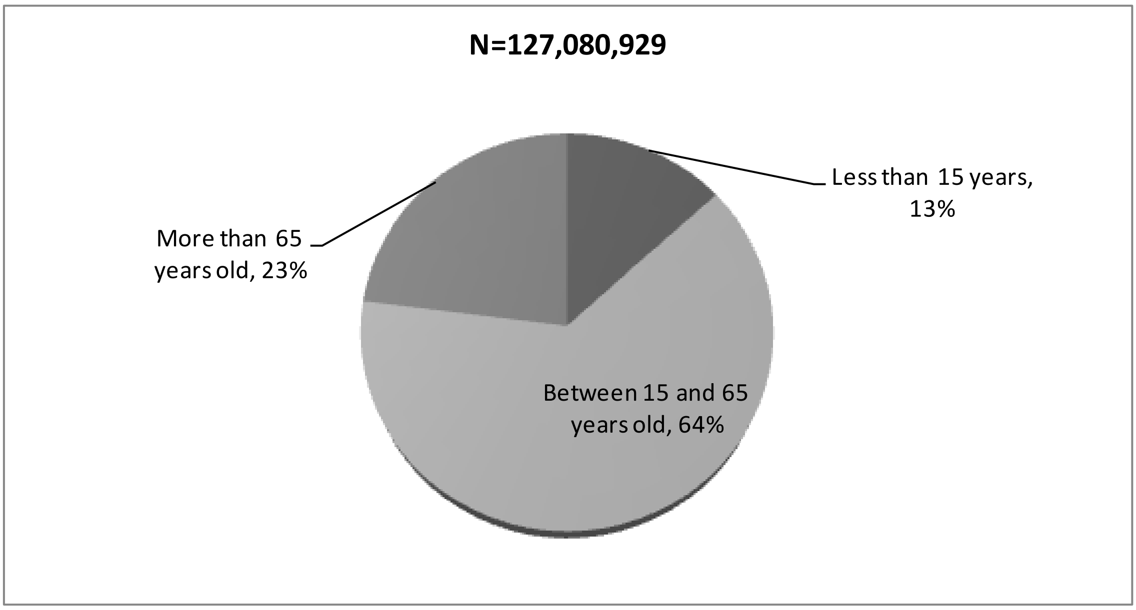
Most Japanese engage in tertiary industry and only 4% of the population are in charge of primary industry like agriculture, forestry and fishery. Japan is famous for manufacturing for export, but only one fourth of the population work in secondary industry.



Source: Ministry of Internal Affairs and Communications (2012), National Census of Japan.

Figure 13 Employees' industry structure in Japan in 2010

It is often said that ageing is progressing in Japan, but 23% of Japanese were over 65 years old in Japan in 2010. On the other hand, only 15% of population were less than 15 years old. In this way, the cause of population decline in Japan is the fertility rate being too low to sustain the population level. These basic national level population situations are introduced in the Statistics Bureau of Japan (2014).



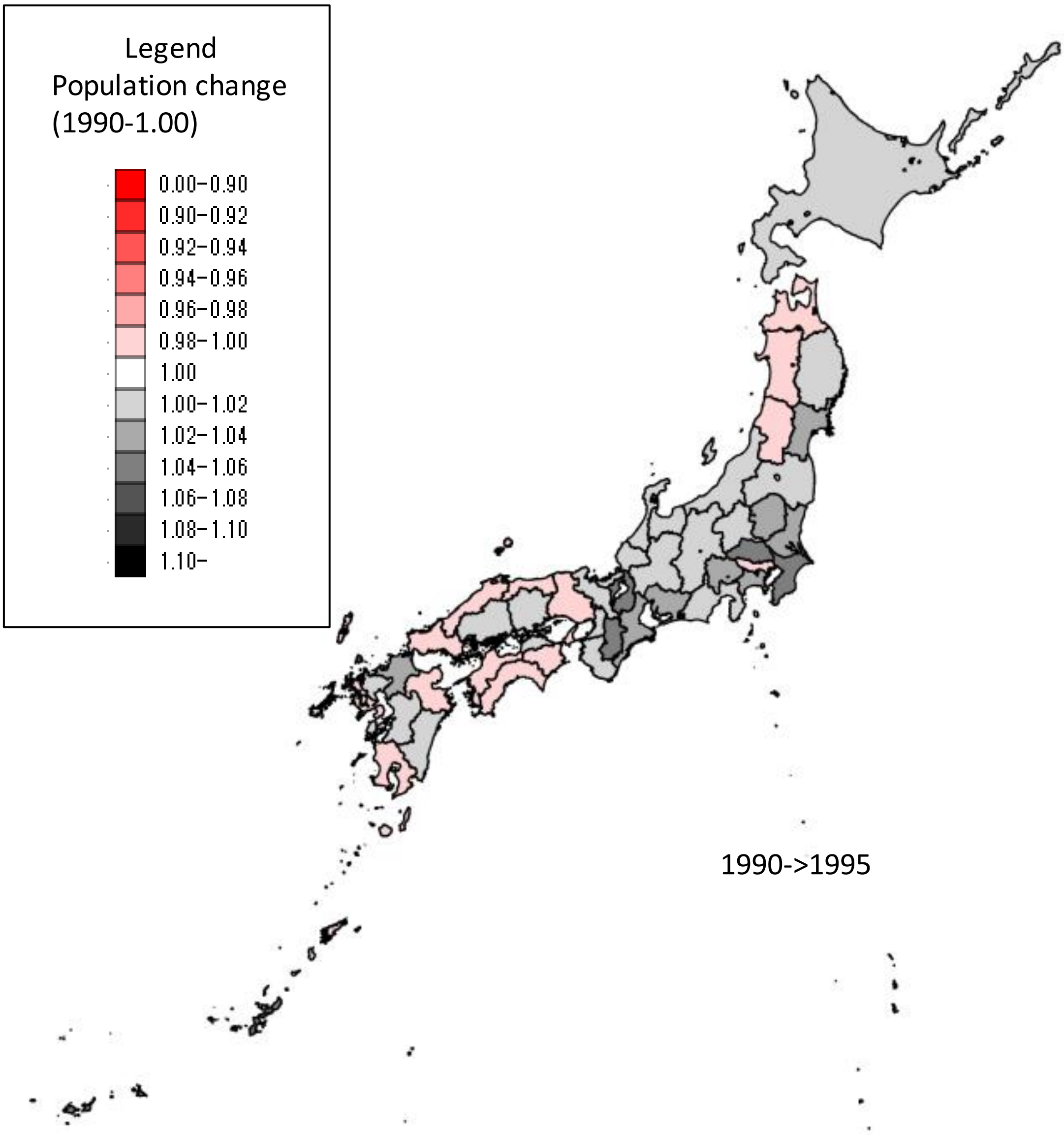
Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 14 Age structure of population in Japan in 2010

3.3.2 Prefectural level of demographic change

The following graphs show the prefectural level of population change in 1995, 2000, 2005 and 2010 expressed as indicators benchmarking to the population in 1990. As shown in the Figure 1, Japan in 1995, 2000, 2005 was still in the population growing era, but Japan in 2010 is different.

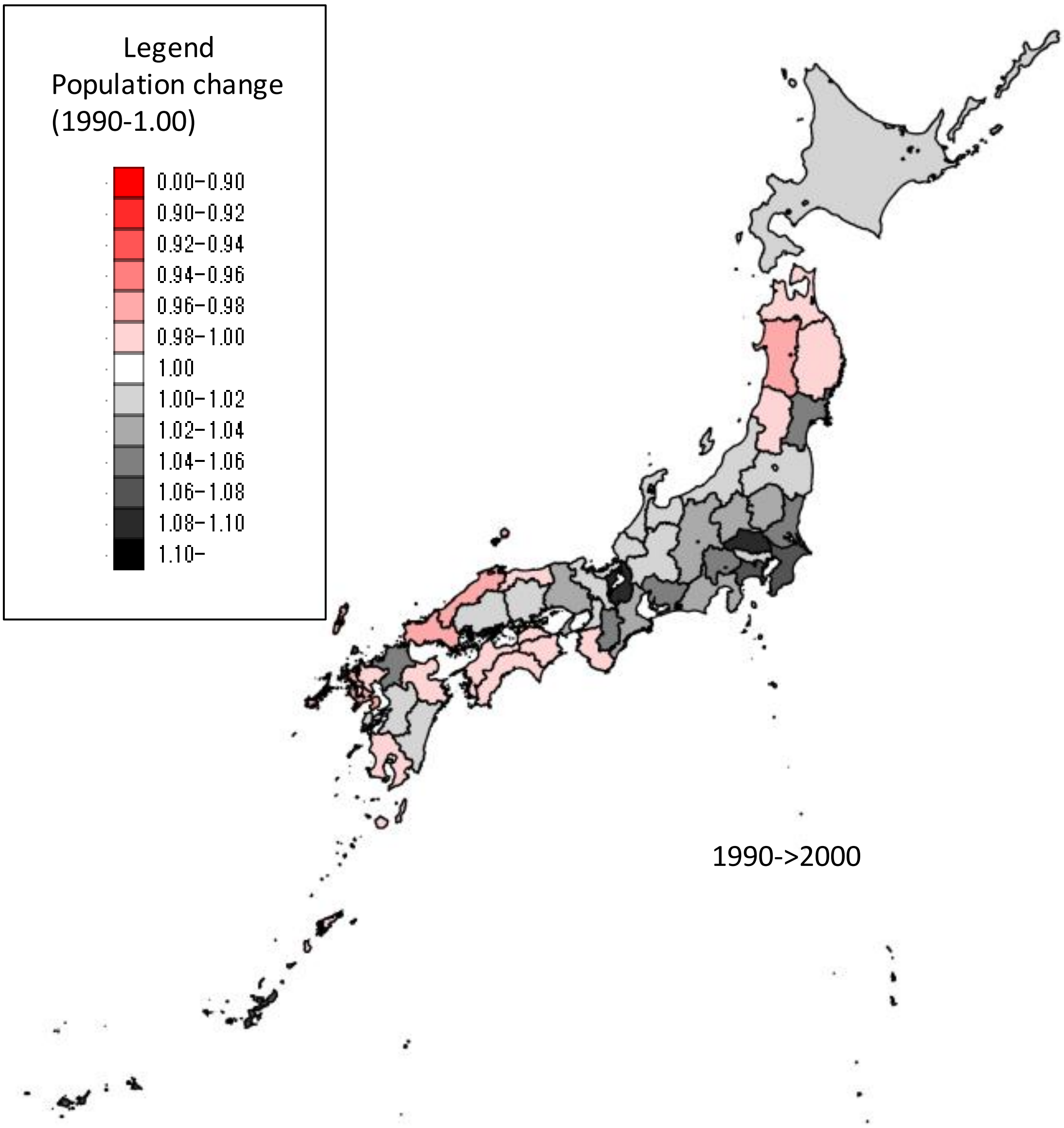
In 1995, most prefectures increased in population, except for Aomori, Akita, Yamagata, Tokyo, Hyogo, Tottori, Shimane Yamaguchi, Tokushima, Ehime, Kouchi, Ooita, and Kagoshima. Apart from Tokyo and Hyogo, those depopulating prefectures are, so to speak, rural prefectures. The reason why Hyogo was depopulating as compared with 1990 was the Great Hanshin Earthquake (January 1995) with 7.3 magnitude. The National Census was conducted on 1st October 1995 and some residents were still evacuated from the city of Kobe.



Source: Ministry of Internal Affairs and Communications (2013), Population Census and Population Estimates.

Figure 15 Population change in prefectures in 1995

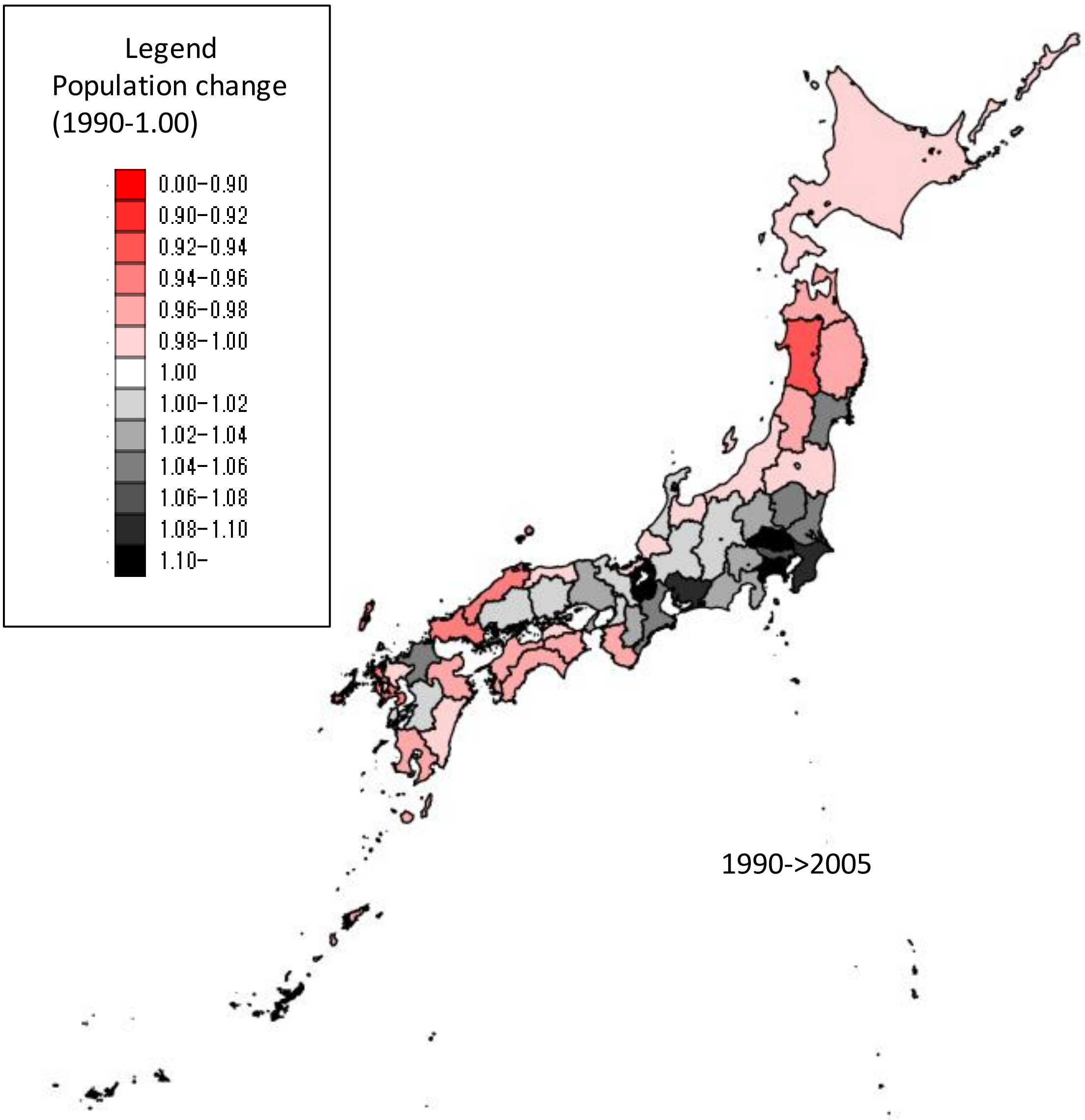
In 2000, Fukushima, Wakayama, Kagawa, Saga and Nagasaki have fallen to depopulating prefectures while Tokyo and Hyogo have recovered to population growing prefectures.



Source: Ministry of Internal Affairs and Communications (2013), Population Census and Population Estimates.

Figure 16 Population change in prefectures in 2000

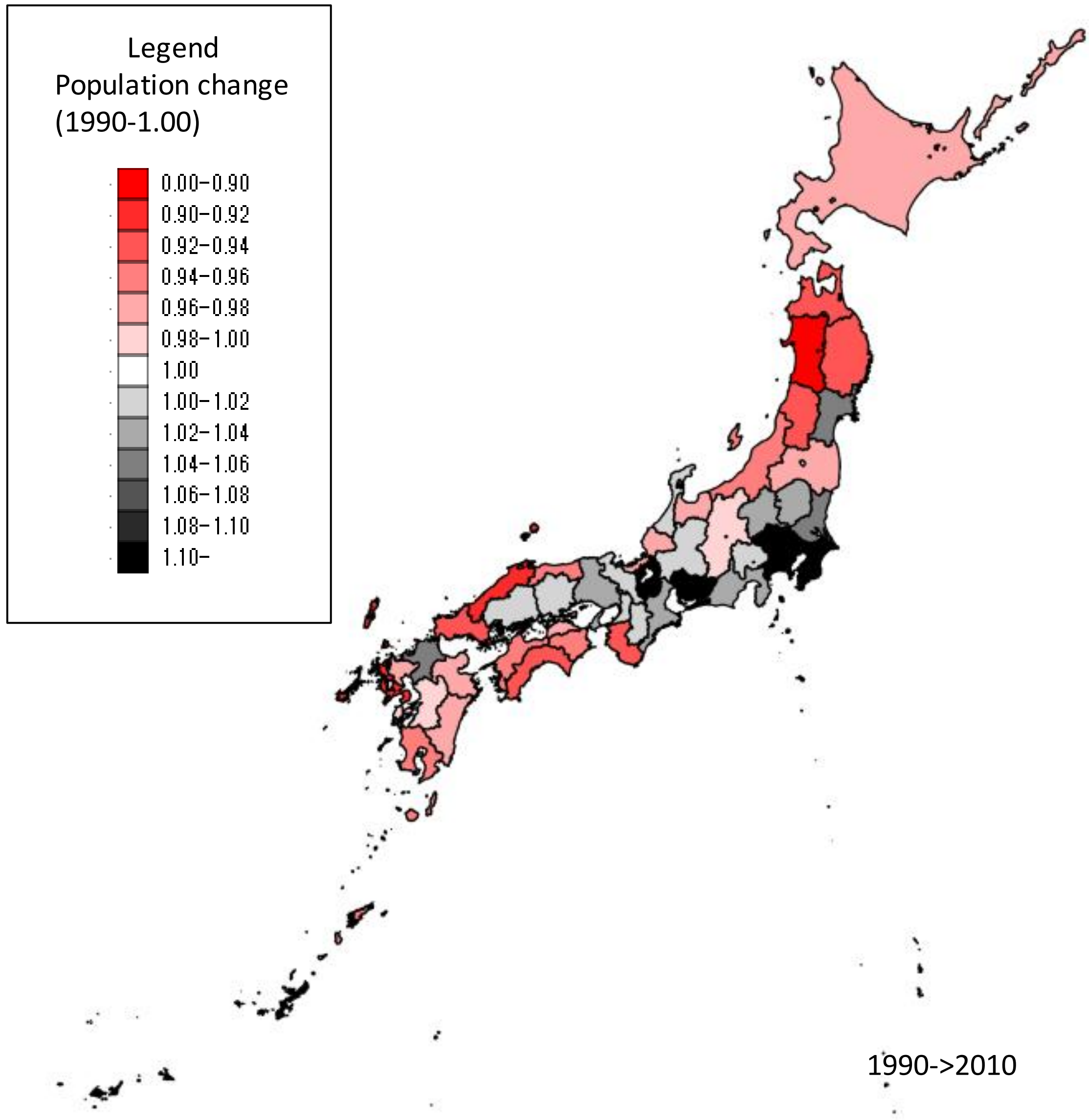
In 2005, Hokkaido, Niigata, Toyama, Fukui, Miyazaki joined the depopulating prefectures. On the other hand, Saitama, Kanagawa, Aichi and Shiga significantly increased in population. Considering population decline in Akita, Shimane and Yamaguchi, the polarization of population trends became obvious in this year.



Source: Ministry of Internal Affairs and Communications (2013), Population Census and Population Estimates.

Figure 17 Population change in prefectures in 2005

The population in 2010 at national level had already peaked, but it was still at the peak while almost half of prefectures had already been depopulating as compared to the population in 1990. In only three metropolitan areas, such as Kanto, Tokai and Kinki, and Miyagi, which is the centre of Tohoku region as well as Fukuoka, which is the centre of Kyusyu region, the population was still growing. However, the other prefectures, in particular, Aomori, Akita, Iwate, Yamagata and Shimane prefecture had significantly decreased in population. Compared with the graph in 2005, Kumamoto and Nagano fell into depopulation.



Source: Ministry of Internal Affairs and Communications (2013), Population Census and Population Estimates.

Figure 18 Population change in prefectures in 2010

In summary, population decline is expanding from rural areas to urban areas. At this moment, only metropolitan areas and regional core areas can sustain their population, but in the near future, some of the prefectures in those areas will also lose their population.

3.3.3 Municipality level of demographic change

Municipalities in Japan are categorized in three types, namely city, town and village. There is a regulatory definition between a city and a town when population is over 50,000 (Local autonomy act, article 8). In addition, most of the municipalities with less than 10,000 are often regarded as depopulating municipalities and supported by central government in various ways. Therefore, when conducting the following study, populations of 10,000 and populations of 50,000 are introduced as the thresholds of population size categories to find the tendency of population change.

As the result of merging municipalities, led by the central government as of 1st October 2010, the number of municipalities with populations of less than 10,000 is lower than the number of municipalities with populations of more than 10,000.

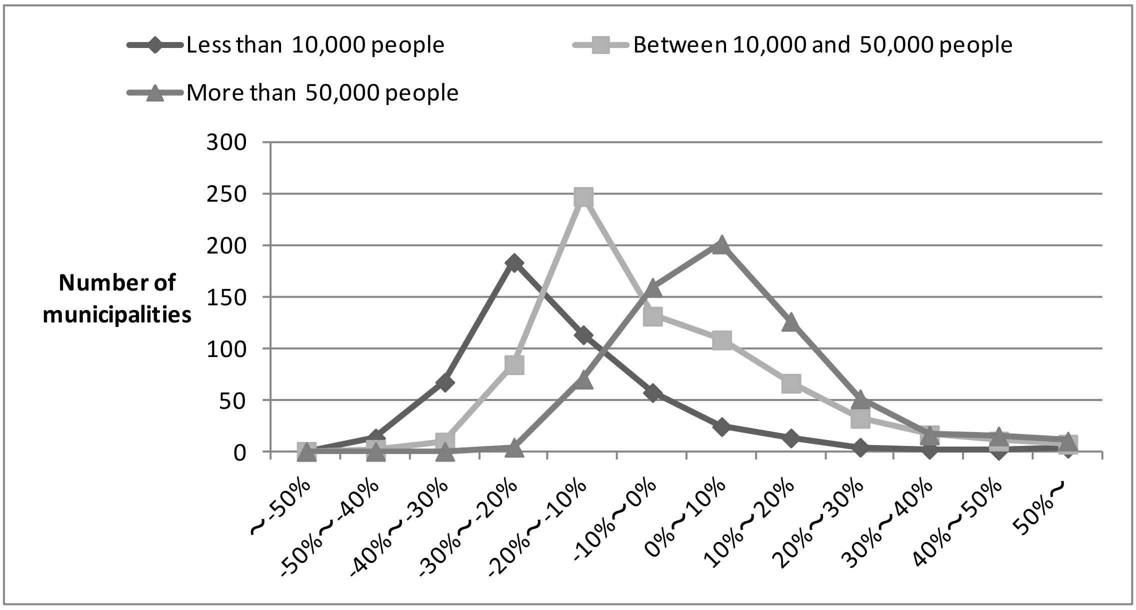
Table 7 Number of municipalities categorized by size of population as of 1st October 2010

Population size in 2010	Number of municipalities
Less than 10,000 people	480
Between 10,000 and 50,000 people	715
More than 50,000 people	706

Note: In ‘more than 50,000 people’, the wards in the ordinance-designated city are counted separately.

Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

The distribution of the rate of population change in those municipalities between 1990 and 2010 is shown in Figure 19. The mode of rate of population change in each category is between -30% and -20% for smaller municipalities, between -20% and -10% for medium size municipalities, and between 0% and 10% for larger municipalities.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 19 Distribution of demographic change in municipalities between 1990 and 2010

The following tables, from Table 8 to Table 16, illustrate the top ten municipalities with population decline in each category, the municipalities with stable populations, and the top ten municipalities with population growth, even in a situation of nationwide depopulation, in each category. The 'map' in the note column of tables means a more highly geographically resolute analysis on population change will be introduced in the following subsections. They are selected because of the extreme value of population change without any specific reason of industrial decline. It is assumed that extreme value in stable population change is almost 0% population change.

Some of severely depopulating municipalities are post mining closure areas. Other municipalities with depopulation are often located in mountain areas or island areas. For the following detailed analysis, Shimkappu, Muroto, and Hagi are selected.

Table 8 Smaller municipalities with population decline

Category	Name of municipality	Prefecture	1990	2010	Rate of population decline	Note
Village	Shimkappu	Hokkaido	2,721	1,394	-48.8%	Map
City	Utashinai	Hokkaido	8,279	4,387	-47.0%	Ex coal mining area
Village	Kawakami	Nara	3,093	1,643	-46.9%	
Village	Ookawa	Kochi	758	411	-45.8%	
Town	Hayakawa	Yamanashi	2,269	1,246	-45.1%	
Town	Rishiri	Hokkaido	4,714	2,590	-45.1%	
Village	Minami-maki	Gunma	4,387	2,423	-44.8%	
Town	Kanna	Gunma	4,159	2,352	-43.4%	
Village	Nosegawa	Nara	926	524	-43.4%	
Village	Kurotaki	Nara	1,472	840	-42.9%	

Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Table 9 Medium sized municipalities with population decline

Category	Name of municipality	Prefecture	1990	2010	Rate of population decline	
City	Yubari	Hokkaido	20,969	10,922	-47.9%	Ex coal mining area
City	Mikasa	Hokkaido	17,049	10,221	-40.0%	Ex coal mining area
City	Akabira	Hokkaido	19,409	12,637	-34.9%	Ex coal mining area
City	Muroto	Kochi	23,308	15,210	-34.7%	Map
City	Ashibetsu	Hokkaido	25,078	16,628	-33.7%	Ex coal mining area
Town	Turugi	Tokushima	15,794	10,490	-33.6%	
Town	Igata	Ehime	16,060	10,882	-32.2%	
Town	Kami-goto	Nagasaki	32,123	22,074	-31.3%	
Town	Minobu	Yamanashi	20,849	14,462	-30.6%	
City	Suzu	Ishikawa	23,471	16,300	-30.6%	

Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Table 10 Larger municipalities with population decline

Category	Name of municipality	Prefecture	1990	2010	Rate of population decline	Note
Ward	Nagata	Hyogo	136,884	101,624	-25.8%	Earthquake suffered
City	Hagi	Yamaguchi	68,999	53,747	-22.1%	Map
Ward	Yawata-higashi	Fukuoka	91,146	71,801	-21.2%	Iron industry decline
City	Amakusa	Kumamoto	112,068	89,065	-20.5%	
City	Minami-shimabara	Nagasaki	62,828	50,363	-19.8%	
City	Uwajima	Ehime	105,030	84,210	-19.8%	
City	Muroran	Hokkaido	117,855	94,535	-19.8%	Iron industry decline
City	Sado	Niigata	78,061	62,727	-19.6%	
City	Otaru	Hokkaido	163,211	131,928	-19.2%	
City	Yuzawa	Akita	62,537	50,849	-18.7%	

Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

On the other hand, there are some municipalities with stable populations. The municipalities selected for the following analysis, Kohoku, Shintom, and Kamakura, have almost 0% population change.

Table 11 Smaller municipalities with stable population trend

Category	Name of municipality	Prefecture	1990	2010	Rate of population change	Note
Town	Goka	Ibaragi	9,468	9,410	-0.6%	
Town	Kohoku	Saga	9,483	9,515	0.3%	Map

Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Table 12 Medium sized municipalities with stable population trend

Category	Name of municipality	Prefecture	1990	2010	Rate of population change	Note
Town	Mitake	Gifu	18,830	18,824	-0.032%	
Town	Shintomi	Miyazaki	18,085	18,092	0.039%	Map
Town	Mibu	Tochigi	39,588	39,605	0.043%	

Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Table 13 Larger municipalities with stable population trend

Category	Name of municipality	Prefecture	1990	2010	Rate of population change	Note
Ward	Yamanashi	Kyoto	136,070	136,045	-0.018%	
City	Kamakura	Kanagawa	174,307	174,314	0.004%	Map
City	Ikeda	Osaka	104,218	104,229	0.011%	

Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Table 14 Smaller municipalities with population growth

Category	Name of municipality	Prefecture	1990	2010	Rate of population growth	Note
Village	Funahashi	Toyama	1,371	2,967	116.4%	Map
Town	Higashi-kagura	Hokkaido	5,763	9,292	61.2%	
Town	Minamihoro	Hokkaido	5,665	8,778	55.0%	
Town	Asahi	Mie	6,744	9,626	42.7%	
Village	Nishihara	Kumamoto	5,024	6,792	35.2%	
Town	Kawakita	Ishikawa	4,554	6,147	35.0%	
Village	Yamagata	Nagano	6,513	8,425	29.4%	
Village	Kita-daito	Okinawa	519	665	28.1%	
Town	Tajiri	Osaka	6,540	8,085	23.6%	
Town	Kamimine	Saga	7,534	9,224	22.4%	

Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Table 15 Medium sized municipalities with population growth

Category	Name of municipality	Prefecture	1990	2010	Rate of population growth	Note
Town	Rifu	Miyagi	16,321	33,994	108.3%	Map
Town	Seika	Kyoto	17,519	35,630	103.4%	
Town	Tomiya	Miyagi	24,611	47,042	91.1%	
Town	Singu	Fukuoka	15,493	24,679	59.3%	
Town	Ina	Saitama	27,100	42,494	56.8%	
Town	Kikuyou	Kumamoto	24,154	37,734	56.2%	
Town	Tamamura	Gunma	24,423	37,536	53.7%	
Town	Namegawa	Saitama	11,566	17,323	49.8%	
Town	Inagawa	Hyogo	21,558	31,739	47.2%	
Village	Nakagusuku	Okinawa	12,060	17,680	46.6%	

Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Table 16 Larger municipalities with population growth

Category	Name of municipality	Prefecture	1990	2010	Rate of population growth	Note
City	Miyoshi	Aichi	32,241	60,098	86.4%	Map
Ward	Chuo	Tokyo	68,041	122,762	80.4%	
City	Mita	Hyogo	64,560	114,216	76.9%	
City	Moriya	Ibaragi	36,427	62,482	71.5%	
City	Nisshin	Aichi	50,335	84,237	67.4%	
City	Shiroi	Chiba	37,082	60,345	62.7%	
City	Iwade	Wakayama	32,846	52,882	61.0%	
City	Inzai	Chiba	55,131	88,176	59.9%	
Ward	Nishi	Hyogo	158,580	249,298	57.2%	
City	Nagakute	Aichi	33,714	52,022	54.3%	

Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

In terms of municipalities with growing populations, Funahashi, Rifu, and Miyoshi are selected. These municipalities are not centre of the region themselves, but municipalities neighbouring regional centres like Toyoma, prefectural capital, Sendai, prefectural capital as well as the centre of Tohoku region, and Nagoya and Toyota, of which the former is the prefectural capital as well as the centre of Tokai region and the latter is the location of headquarters of the Toyota motor corporation. Other municipalities apart from selected municipalities are also often located in the suburbs of the central city of the region and developed as a dormitory town for commuters.

3.3.4 MESH LEVEL OF DEMOGRAPHIC CHANGE

For the mesh level spatial analysis, the following nine municipalities were selected from the perspective of both population size and population change. The selected municipalities are totally scattered, all over Japan.

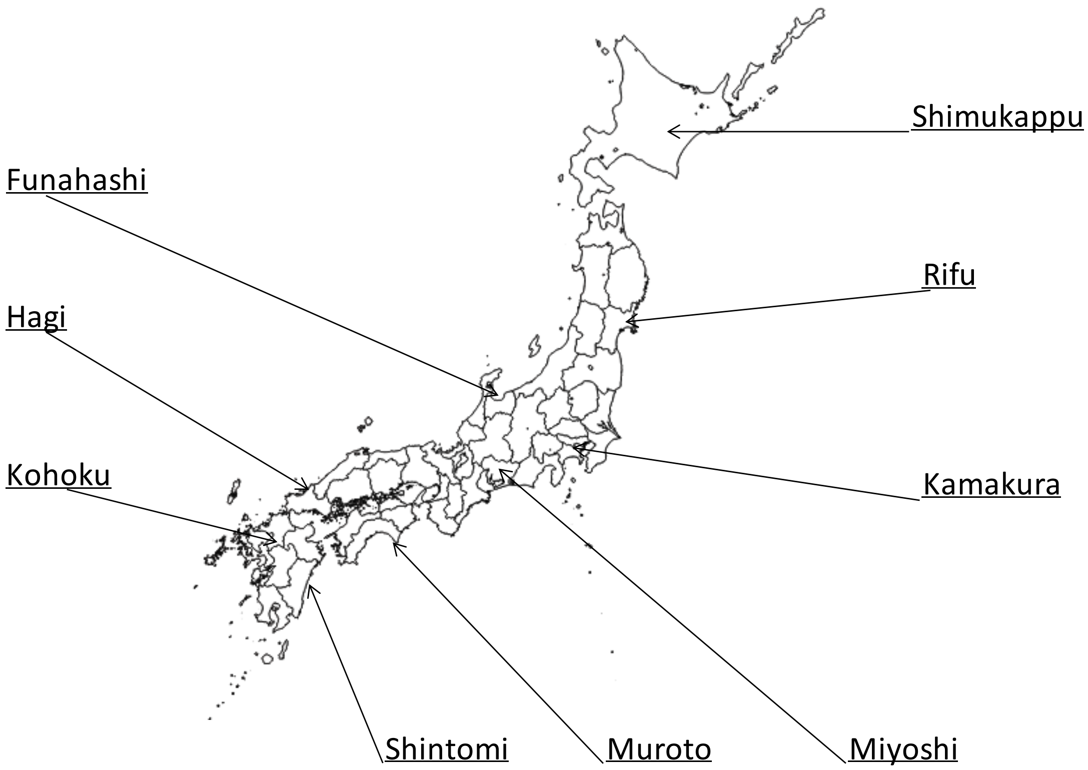


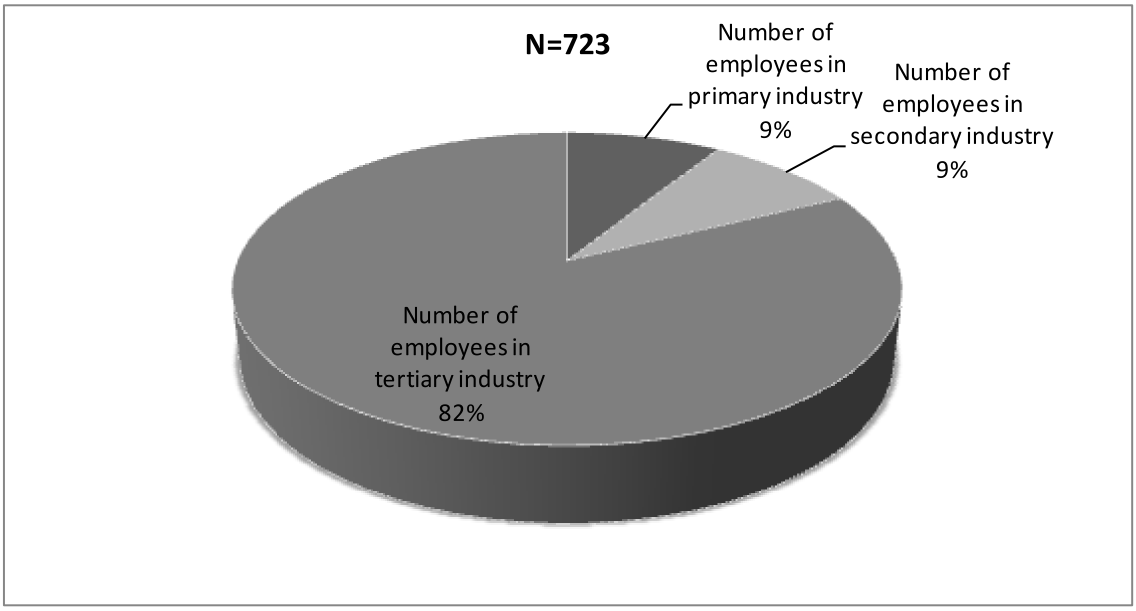
Figure 20 Location of the case study municipalities

3.3.4.1 Population decline

3.3.4.1.1 Shimkappu

The village of Shimkappu is located in the centre of the Hokkaido Island and far from Sapporo which is regional centre of Hokkaido region.

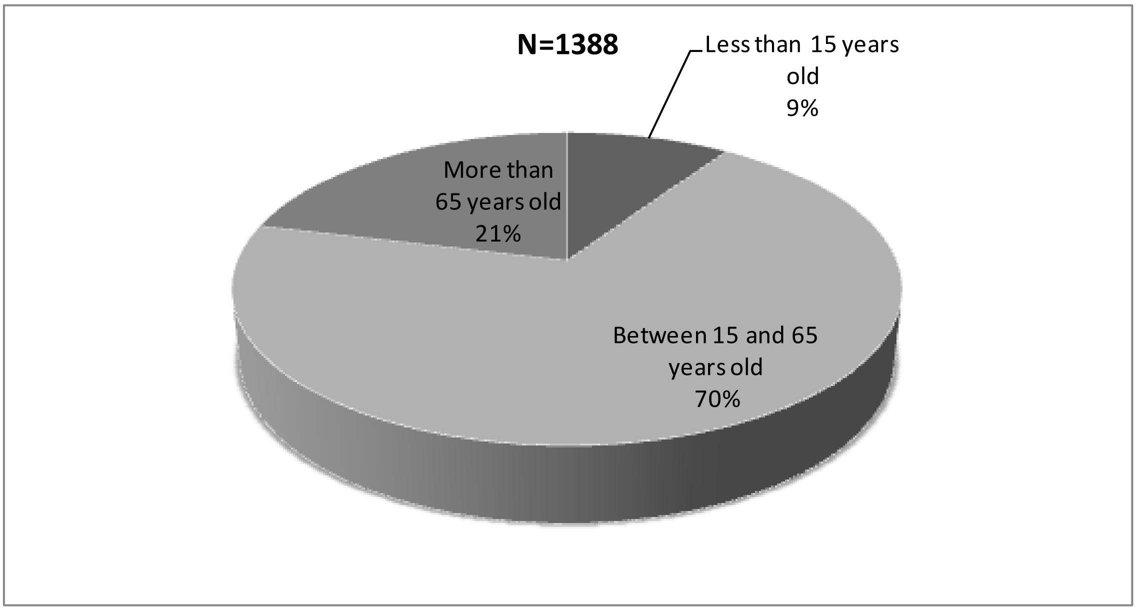
This municipality is famous as a winter ski resort, so the main industry of this municipality is the tertiary industry of tourism and so on.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 21 Employees' industry structure in the village of Shimkappu in 2010

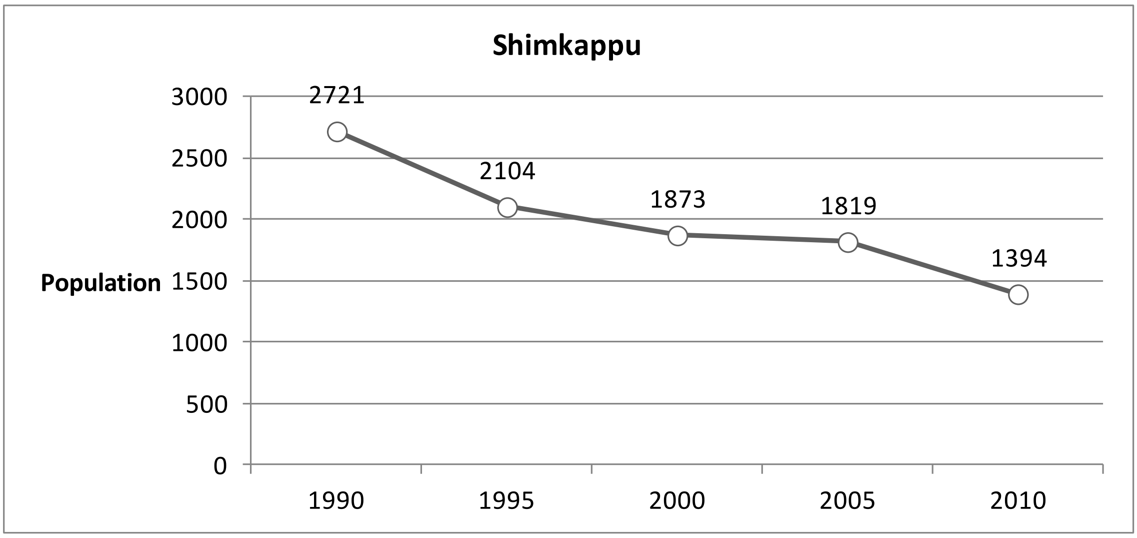
According to the industry structure, even in a depopulating area, the young population, in particular, the working age population is the larger.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 22 Age structure of population in the village of Shimkappu in 2010

In terms of the trend of population change, the population is constantly declining and the population in 2010 has become almost half as much as the population in 1990. The main reason pointed out by the municipality is the decline in agricultural industry and also restructuring of dormitories for the employees of resort facilities in the Tomamu area. The farmers stop working in production and have gradually moved out. In addition, the resort industry has also reorganized their business several times in this period. It can be considered that industry transformation may affect the population change.

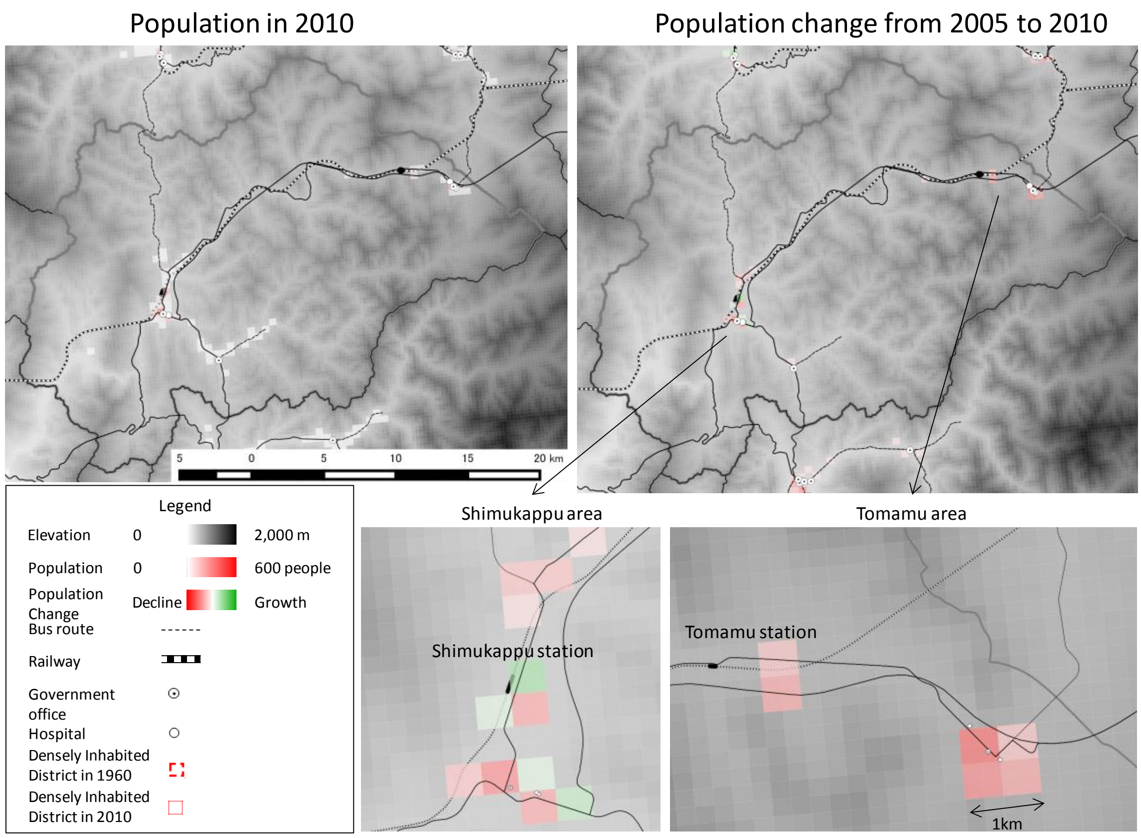


Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 23 Population trend in Shimkappu between 1990 and 2010

The population distribution in the village is polarized in two regions, Shimukappu district (left hand side) and Tomaku district (right hand side). Shimukappu district is the centre of this village.

Apart from those two districts. There is almost no population in the village because of the severe terrain. In terms of population change between 2005 and 2010 in the mesh resolution, some of mesh near the station and along the bus route may have increased in population in Shimukappu, but simultaneously, the mesh next to the government office and hospitals has lost population. In the Tomamu district, all mesh with population has lost its population.



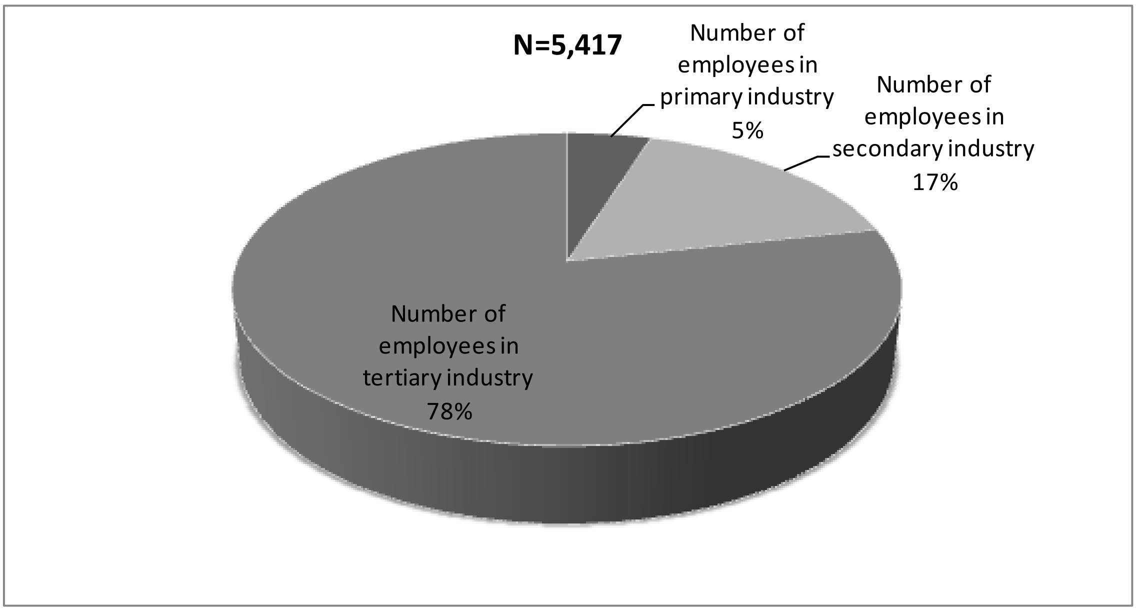
Source: National Land Numerical Information Data (City Areas (surface), Densely Inhabited District (surface), Elevation, Degree of Slope 5th Mesh Data, Medical Organization (point), Local Government Office, etc. and Public Meeting Facility (point), Railways (line), Bus route (line)).

Figure 24 Population distribution and population change in the village of Shimkappu

3.3.4.1.2 Muroto

The city of Muroto is famous for fishery and whale watching, and located on the eastern side of Kochi prefecture. The distance between Muroto and Kochi, which is the prefectural capital, is almost 70–80km and it takes almost two hours to drive and is without railway connection.

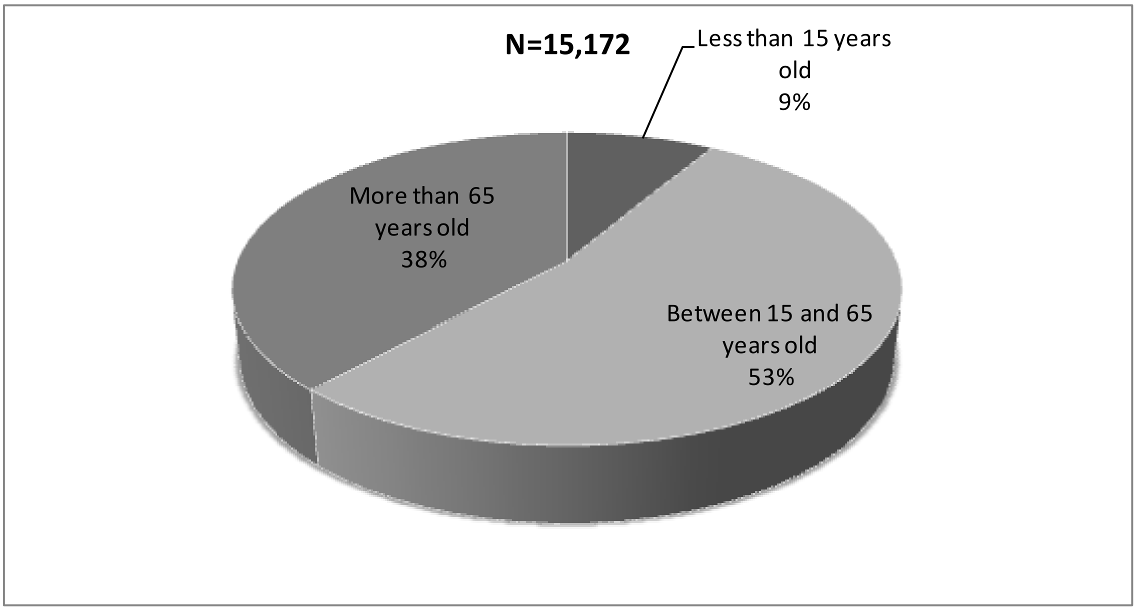
Because of the decline in the fishery industry, the composition of the employees in the primary industry and the secondary industry including food processing is not so large now.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 25 Employees' industry structure in the village of Muroto in 2010

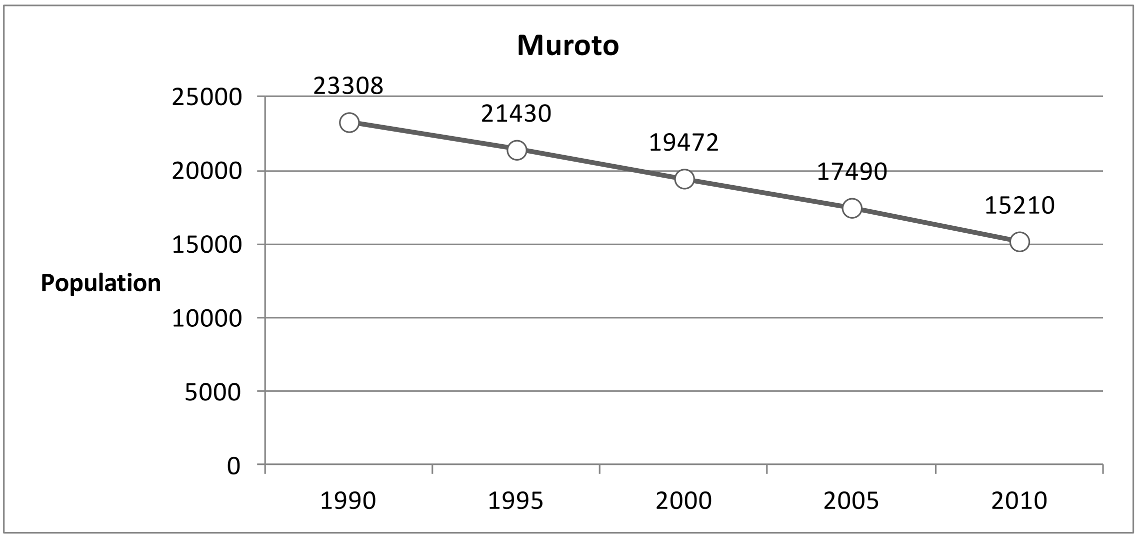
Accordingly, the population in this area is ageing, with almost 40% over 65 years old.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 26 Age structure of population in the village of Muroto in 2010

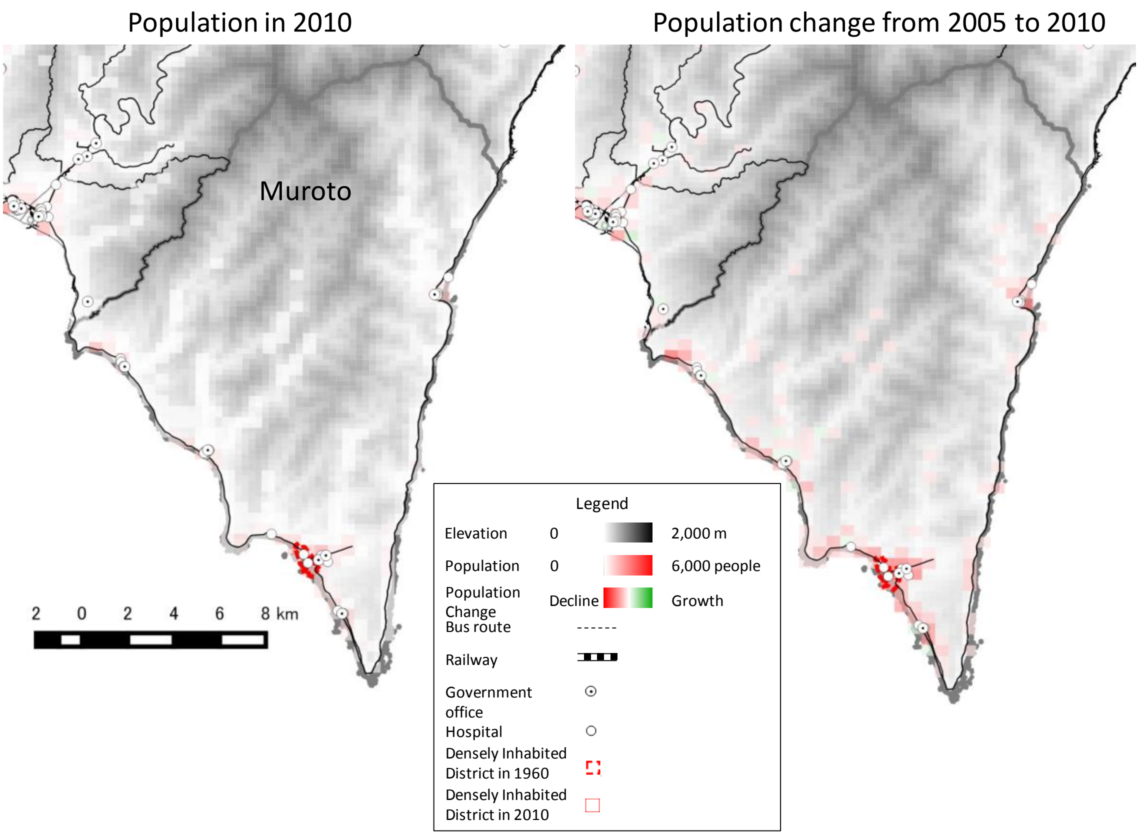
The trend of population change is constantly declining and the population has become almost three fifths what it was 20 years ago.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 27 Population trend in Muroto between 1990 and 2010

Muroto is also a mountainous area and inhabitable areas are very limited within the municipality boundary. Accordingly, the population is stuck along the coast line as well as in the valley. With the population in decline for a couple decades, the densely inhabited district in Muroto has disappeared. On the other hand, despite the constant population decline in this city, some of the mesh is able to show a small increase in the population outside the central district. The location of these areas is also not related to bus routes, hospitals and government offices and so on.



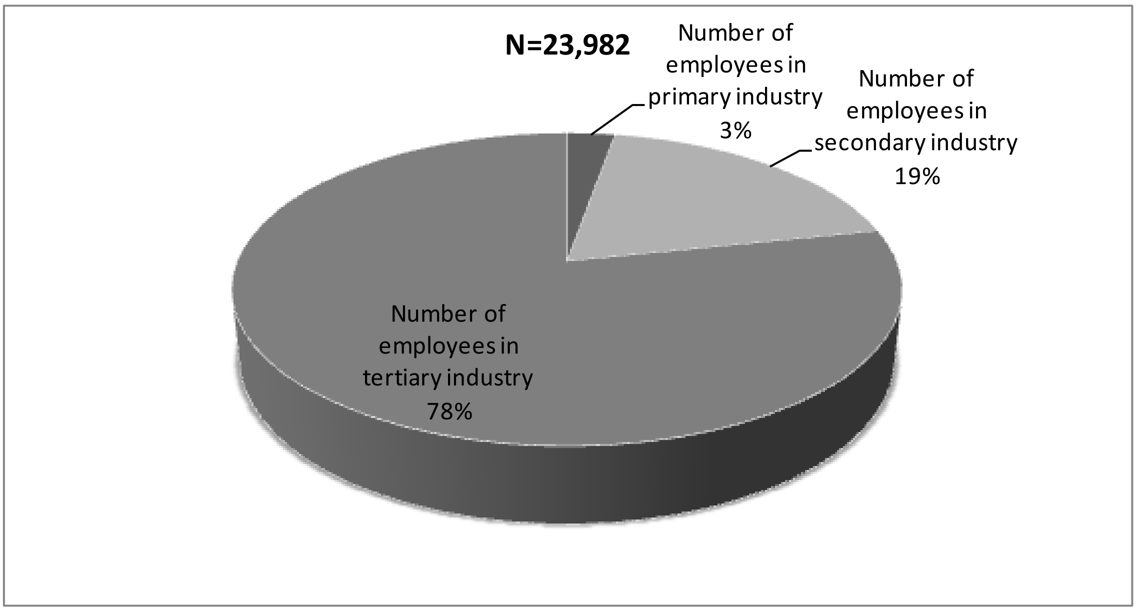
Source: National Land Numerical Information Data (City Areas (surface), Densely Inhabited District (surface), Elevation, Degree of Slope 5th Mesh Data, Medical Organization (point), Local Government Office, etc. and Public Meeting Facility (point), Railways (line), Bus route (line)).

Figure 28 Population distribution and population change in the city of Muroto

3.3.4.1.3 Hagi

Hagi was previously regional capital in the Chosyu Domain in the Edo era. After Meiji civil war, the regional capital moved to the city of Yamaguchi. Since then, Hagi was become one of the local cities. This area has very limited connection to highway and Shinkansen, so that it is very difficult to invite secondary industry for creating job opportunities.

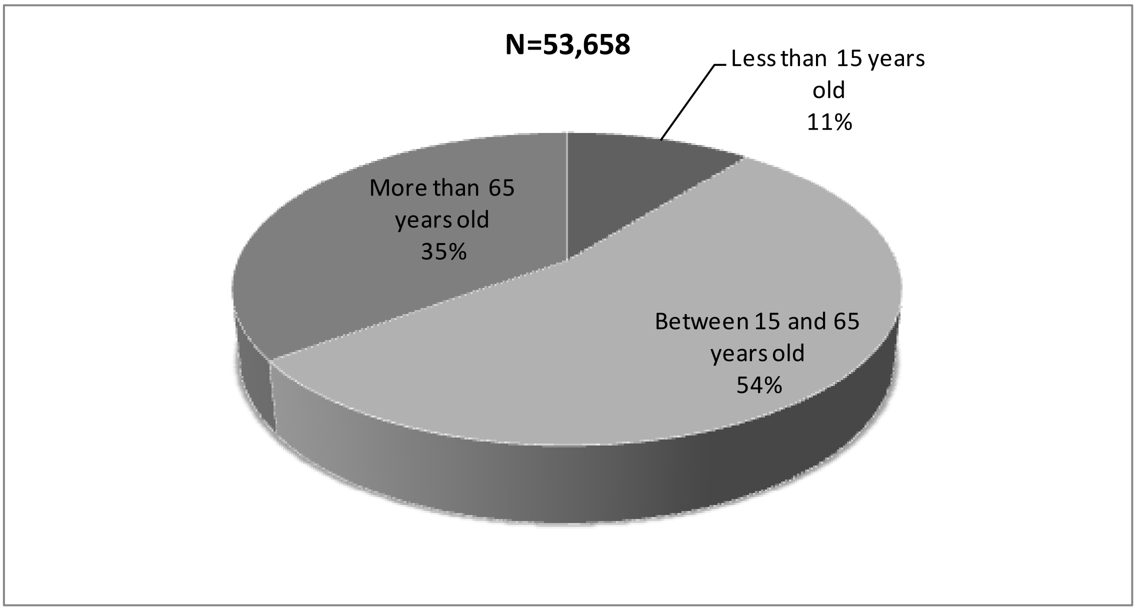
The main industry is, one can easily assume, tourism.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 29 Employees' industry structure in the village of Hagi in 2010

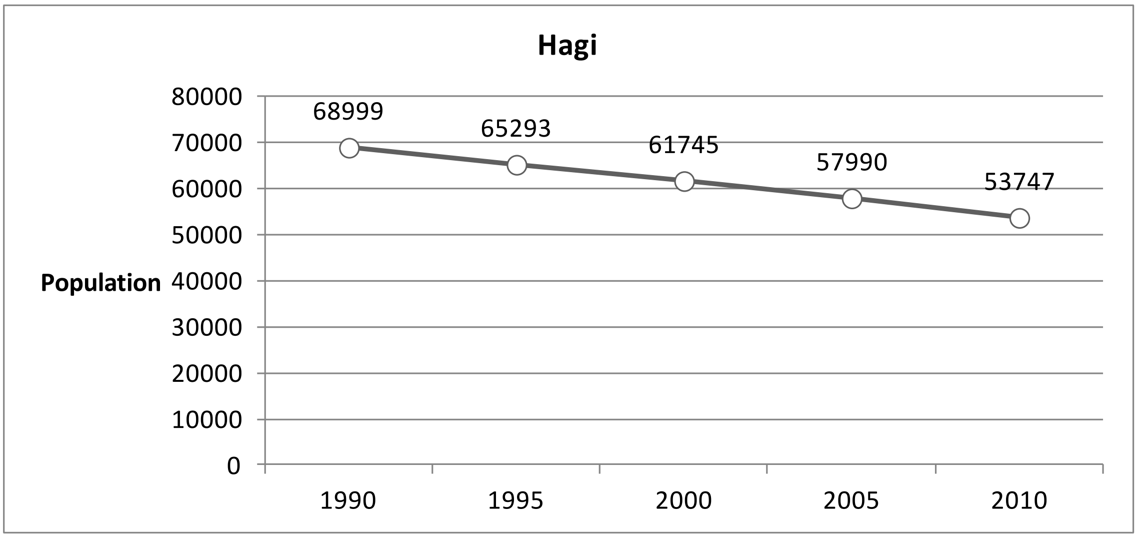
The population composition is also leaning towards the aged.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 30 Age structure of population in the village of Hagi in 2010

The population is constantly declining because of the tourist industry's decline.



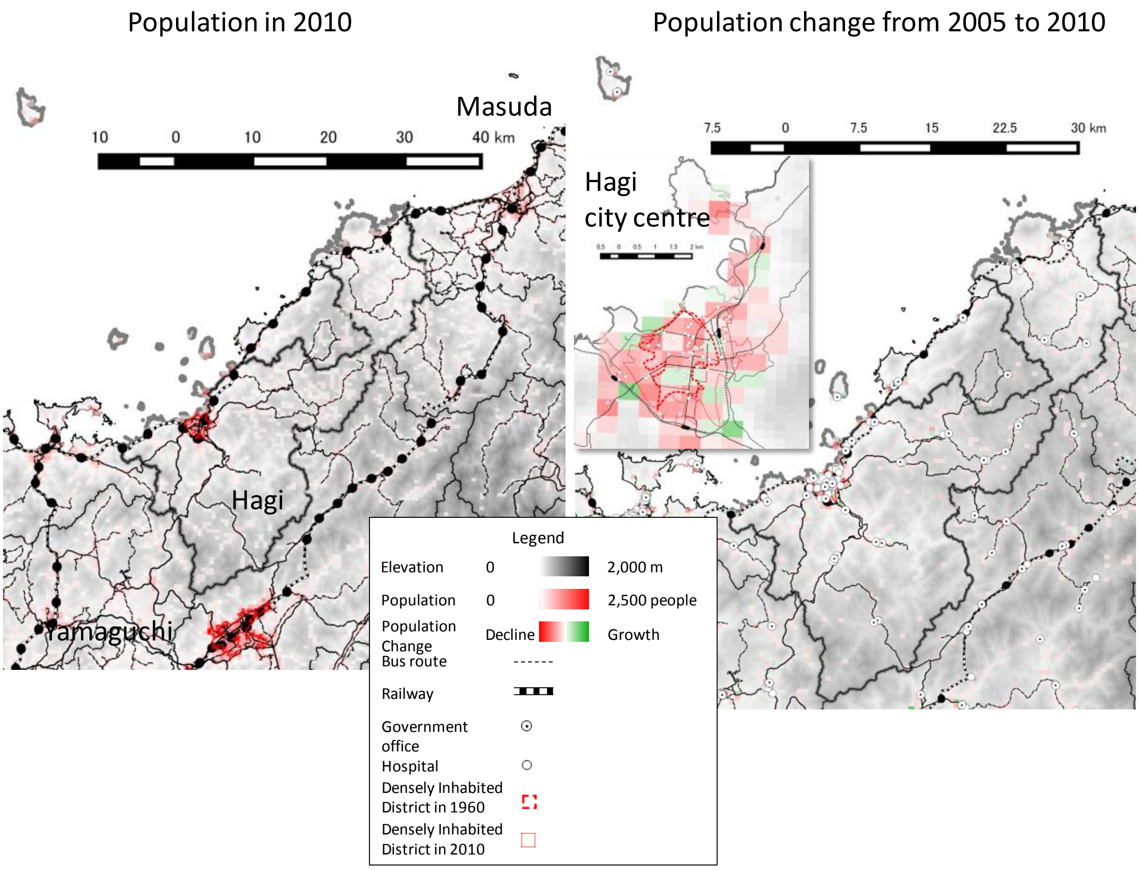
Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 31 Population trend in Hagi between 1990 and 2010

Hagi has enlarged its municipal boundary after merging with other small municipalities. After that, the area of the city of Hagi has become very wide and the population is also scattered all over the municipality area. As in Muroto, the terrain of this city is also severe, so that the population can only be distributed in the valley or small plain along the coastline.

Population change is also disparate. Even in the mountain area, some of the mesh can obtain a small extent of population growth, but even in the city centre of Hagi, most of the mesh has lost its population. It is very difficult to find any relationship between population change and infrastructure like government offices, railway services and bus routes.

Interestingly, the mesh with population growth in the city centre of Hagi is outside the densely inhabited district in 2010. It means that the sprawl of the urban area has still progressed even in this severely depopulating area in Japan.



Source: National Land Numerical Information Data (City Areas (surface), Densely Inhabited District (surface), Elevation, Degree of Slope 5th Mesh Data, Medical Organization (point), Local Government Office, etc. and Public Meeting Facility (point), Railways (line), Bus route (line)).

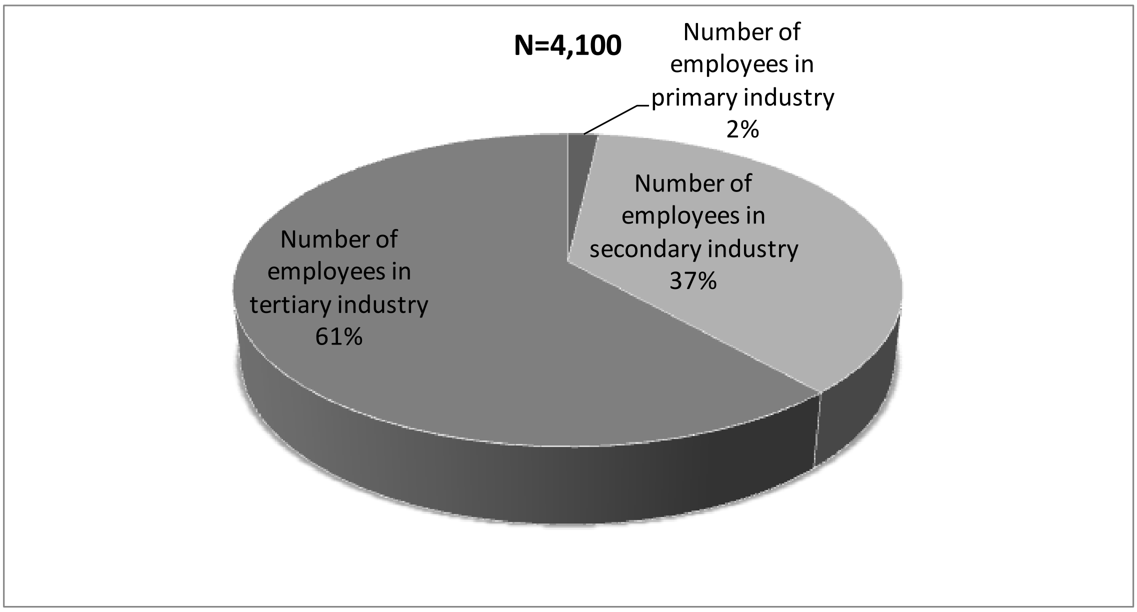
Figure 32 Population distribution and population change in the city of Hagi

3.3.4.2 Stable population

3.3.4.2.1 Kohoku

Kohoku is located only 10km from the city of Saga where the capital of Saga prefecture is. This town is historically the transportation hub of the railway. In the Shinkansen development plan, the branch point will, however, move from the Hizen Yamaguchi station in Kohoku to Takeo Onsen station. Therefore, the future environment of regional development in this town is not certain because in many cases when the Shinkansen station is no longer located in an area a shift of economy will happen from that area to another area.

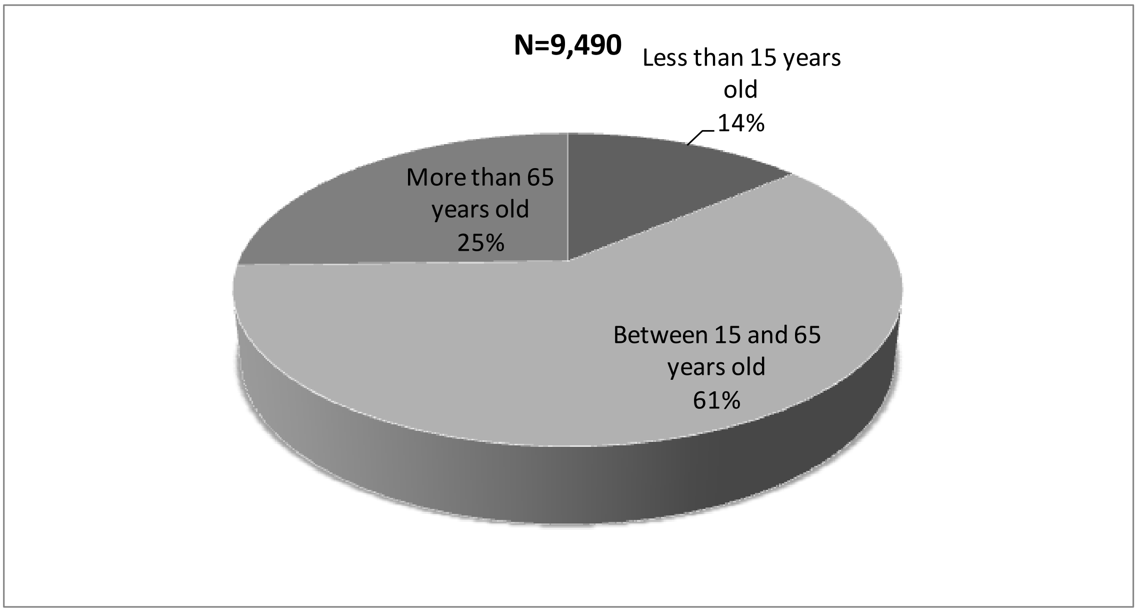
The town has some of factories, so the number of employees in secondary industry is bigger.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 33 Employees' industry structure in the village of Kohoku in 2010

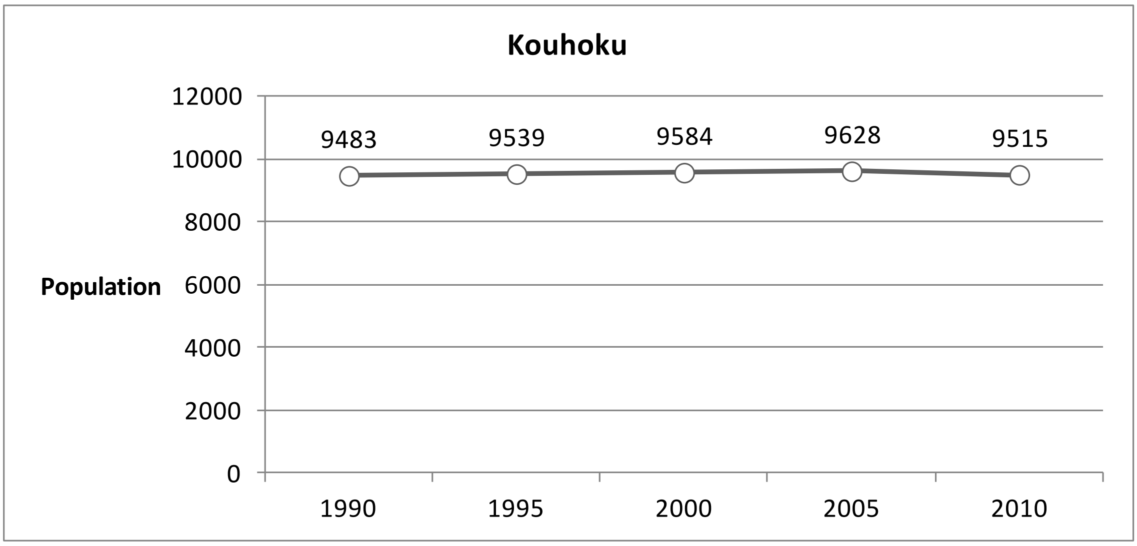
The population is also still young and only 25% of people are more than 65 years old. In addition, the age composition here is almost the same as the national average.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 34 Age structure of population in the village of Kohoku in 2010

The population trend is almost stable but peak population was in 2005.

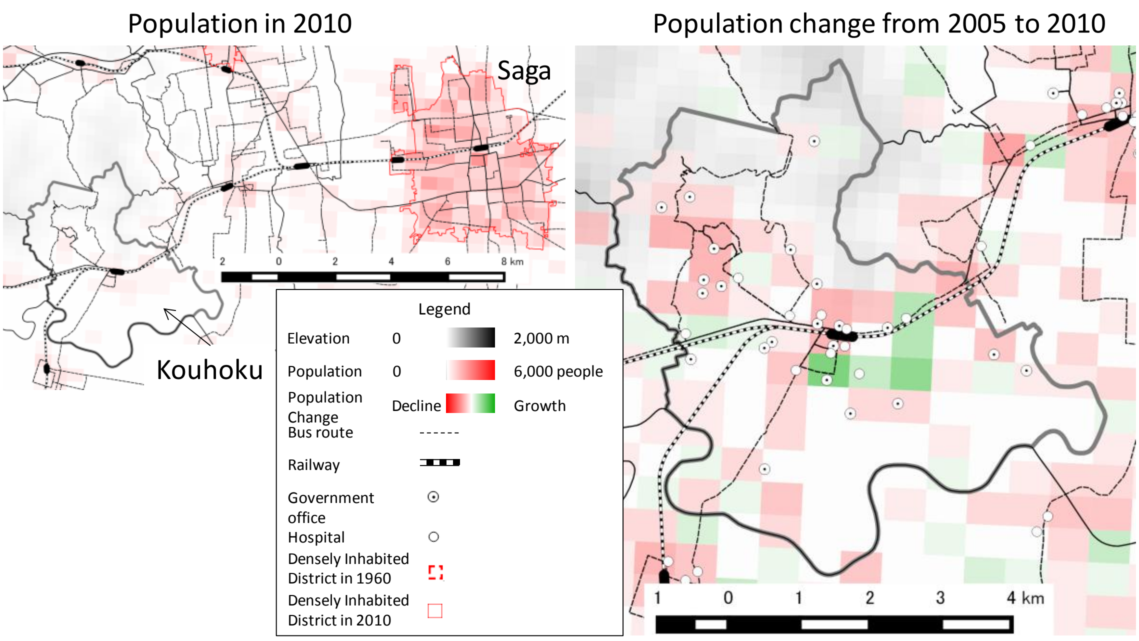


Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 35 Population trend in Kohoku between 1990 and 2010

The town of Kohoku did not have any densely inhabited districts in 1960 or 2010. The population is distributed near the station as well as the basin in the north part.

The population decline is observed near the government offices and station while the population growth is observed in the area 1–2km away from the station. The depopulating areas are the old parts of the town, and the population growth area is the newly developed area converted from rice paddies. Accordingly, this population change can be considered as sprawling, but it happens on a very small scale.



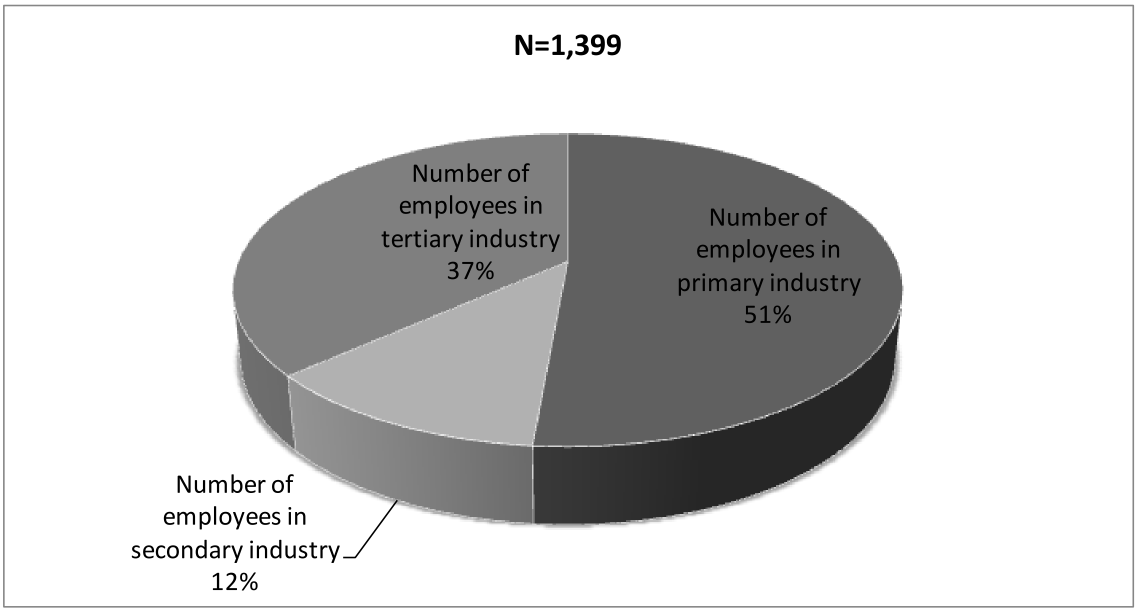
Source: National Land Numerical Information Data (City Areas (surface), Densely Inhabited District (surface), Elevation, Degree of Slope 5th Mesh Data, Medical Organization (point), Local Government Office, etc. and Public Meeting Facility (point), Railways (line), Bus route (line)).

Figure 36 Population distribution and population change in the town of Kohoku

3.3.4.2.2 Shintomi

Shintomi is east of the city of Saito, which is the historical capital of the region, and also 10km north of Miyazaki, which is the prefectural capital now.

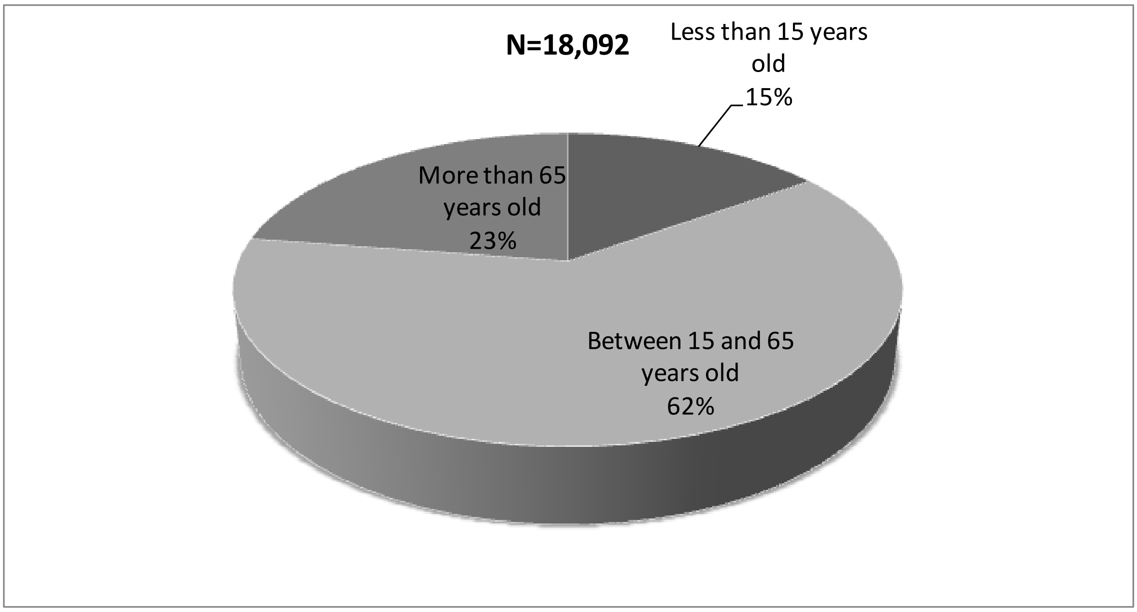
This town has an air base called the Newtabaru and is also famous for the horticulture of green pepper, tomato, cucumber and so on. Accordingly, the employees in the primary industry are dominant in the composition of industry structure.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 37 Employees' industry structure in the village of Shintomi in 2010

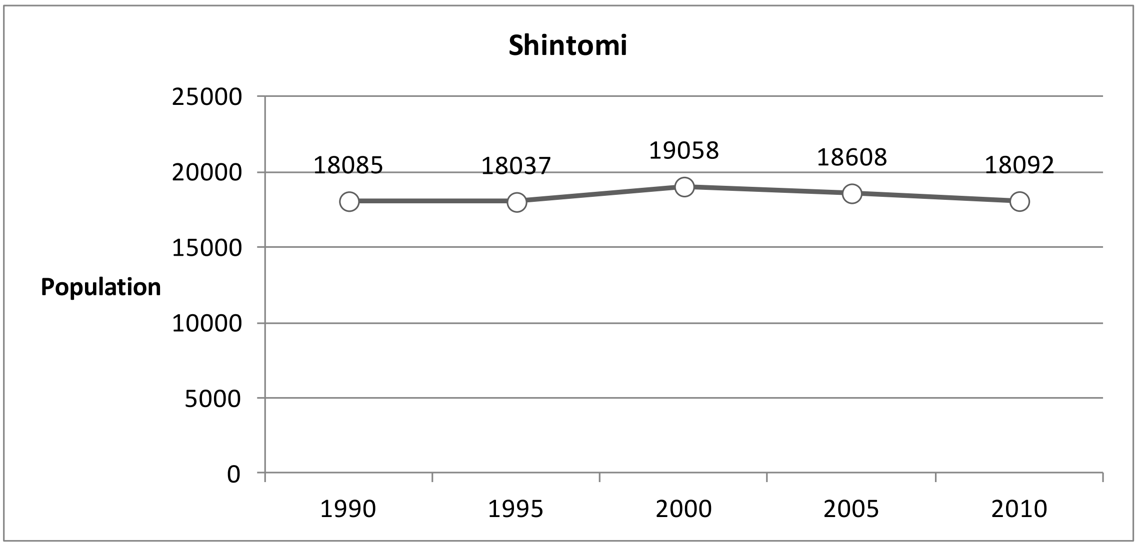
This is a rural area and the main source of employment is the primary industry and the air base, but the age structure of this town is still slightly younger than national average.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 38 Age structure of population in the village of Shintomi in 2010

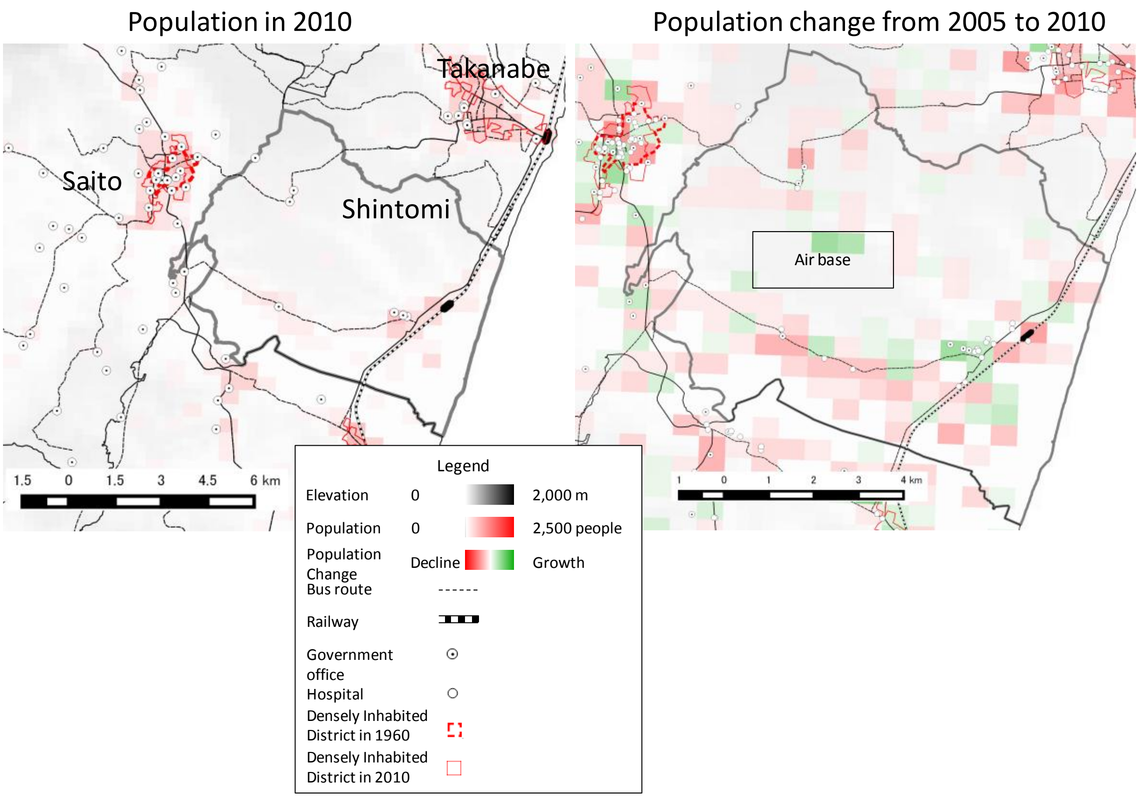
The population trend is slightly fluctuating but still almost stable.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 39 Population trend in Shintomi between 1990 and 2010

Population distribution concentrates in the basin area of the Hitotsuse River, but a small number of the population live on the hills. Population growth is mainly observed in the area 1km away from the station and near to the government facility, but the other areas in the basin and hill area away from the air base are losing their population.



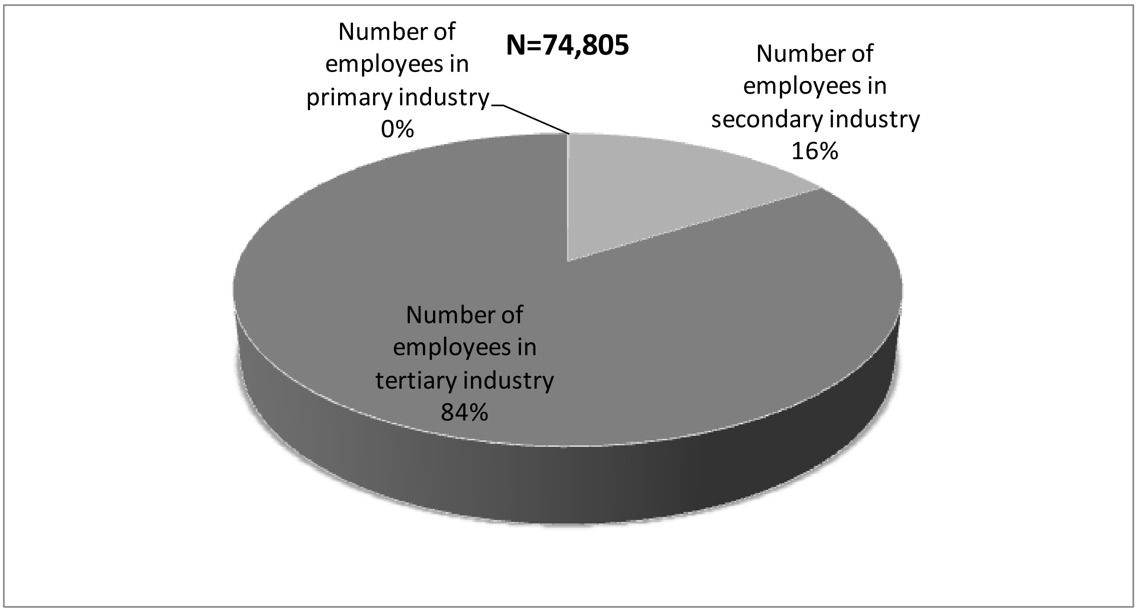
Source: National Land Numerical Information Data (City Areas (surface), Densely Inhabited District (surface), Elevation, Degree of Slope 5th Mesh Data, Medical Organization (point), Local Government Office, etc. and Public Meeting Facility (point), Railways (line), Bus route (line)).

Figure 40 Population distribution and population change in the town of Shintomi

3.3.4.2.3 Kamakura

Kamakura is, of course, the area famous for sightseeing historical places. It is located just next to the city of Yokohama and recognized as the dormitory town of Tokyo and Yokohama.

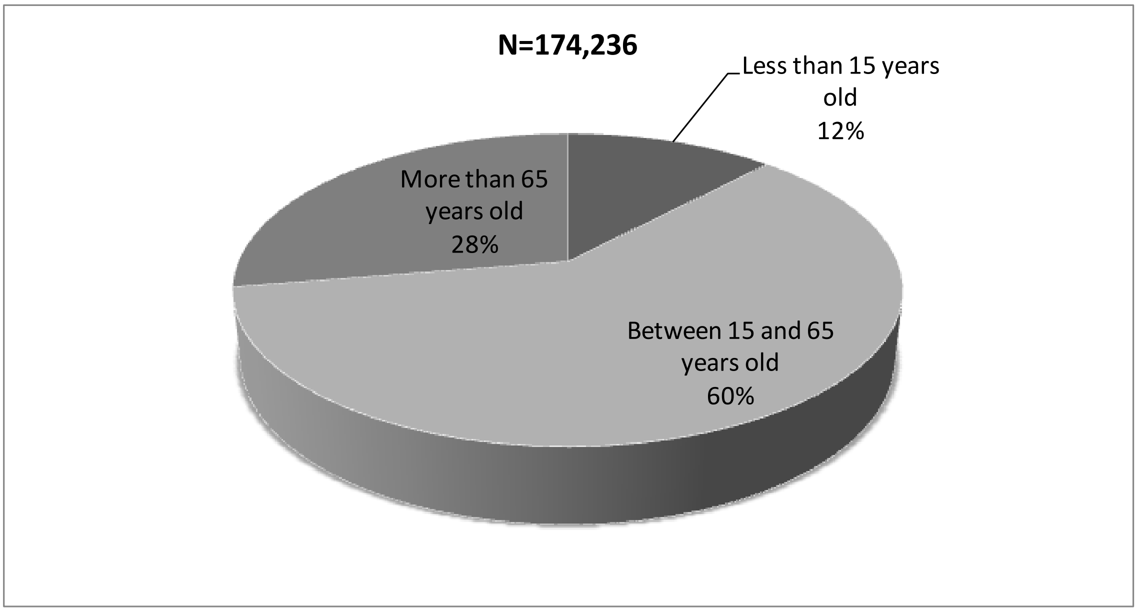
Accordingly, the associated industry employing most residents is tertiary.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 41 Employees' industry structure in the village of Kamakura in 2010

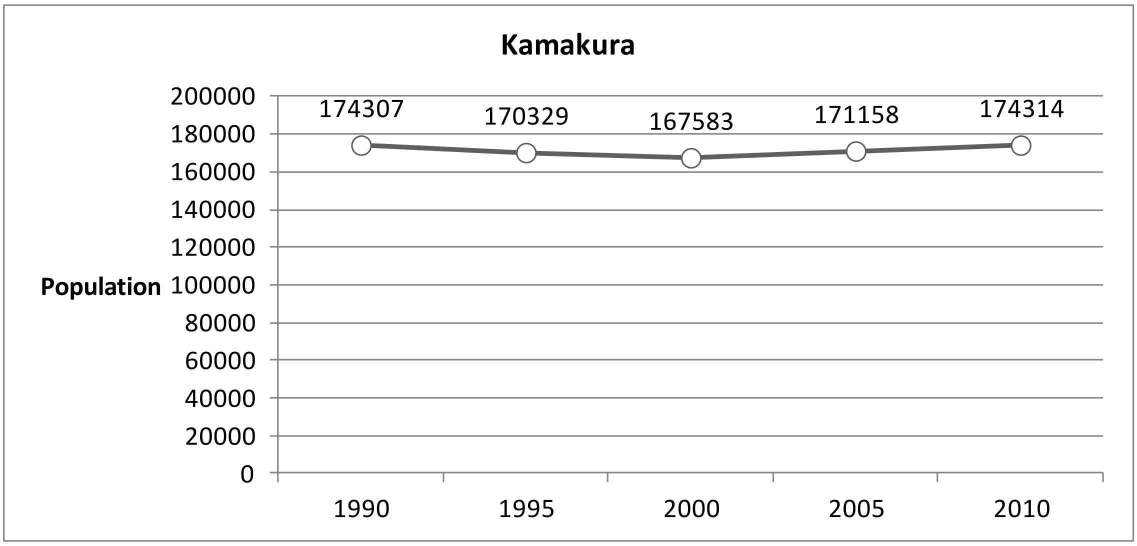
The age structure is also almost the same as the age structure of the whole country.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 42 Age structure of population in the village of Kamakura in 2010

The population trend was in decline until 2000, but recovered from 2005. Now, the population is more than that in 1990.

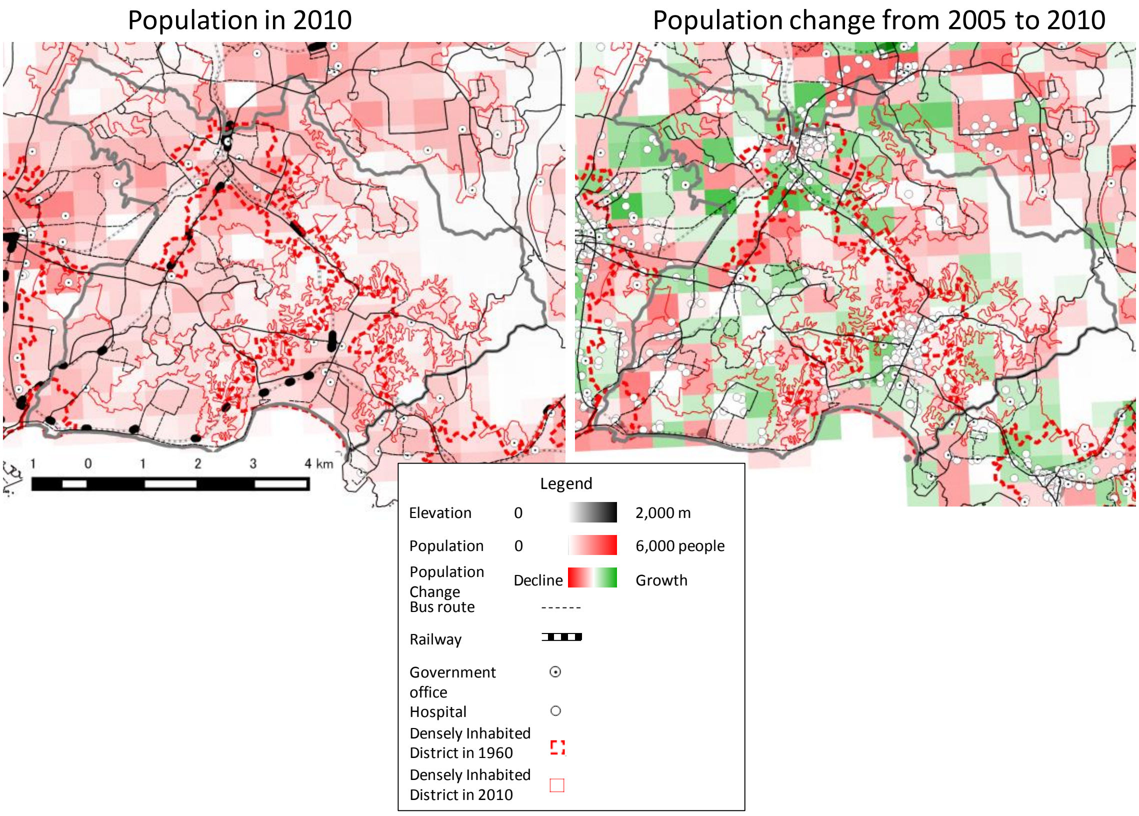


Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 43 Population trend in Kamakura between 1990 and 2010

This area had a densely inhabited district (DID) in 1960 and 2010 but the area of DID has expanded from 1960 to 2010. The concentration of population is observed in the northern part but also most of city area has population apart from the small mountains (on the east side of the city).

Population change is also rather disparate. Next to the mesh with population increase, the mesh with population decline can be observed. This change doesn't have any remarkable relationship to the station, government officer, hospital and so on. One can only say that the population decline meshes and population increase meshes are mixed half and half.



Source: National Land Numerical Information Data (City Areas (surface), Densely Inhabited District (surface), Elevation, Degree of Slope 5th Mesh Data, Medical Organization (point), Local Government Office, etc. and Public Meeting Facility (point), Railways (line), Bus route (line)).

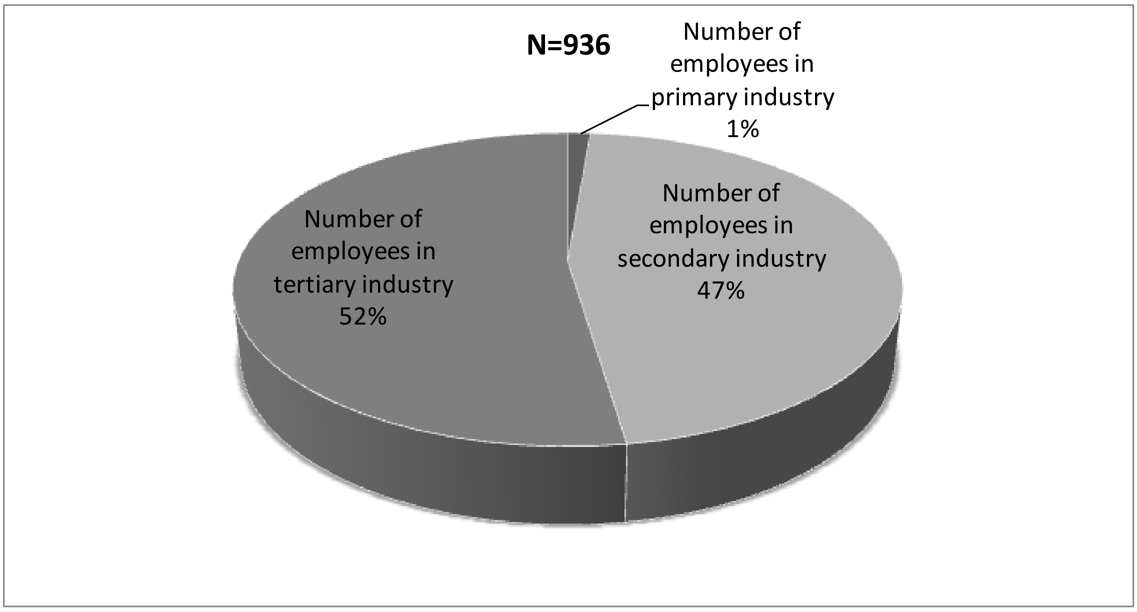
Figure 44 Population distribution and population change in the city of Kamakura

3.3.4.3 Population growth

3.3.4.3.1 Funahashi

Funahashi is located less than 10km to the east of Toyama city centre, which is the prefectural capital of Toyama.

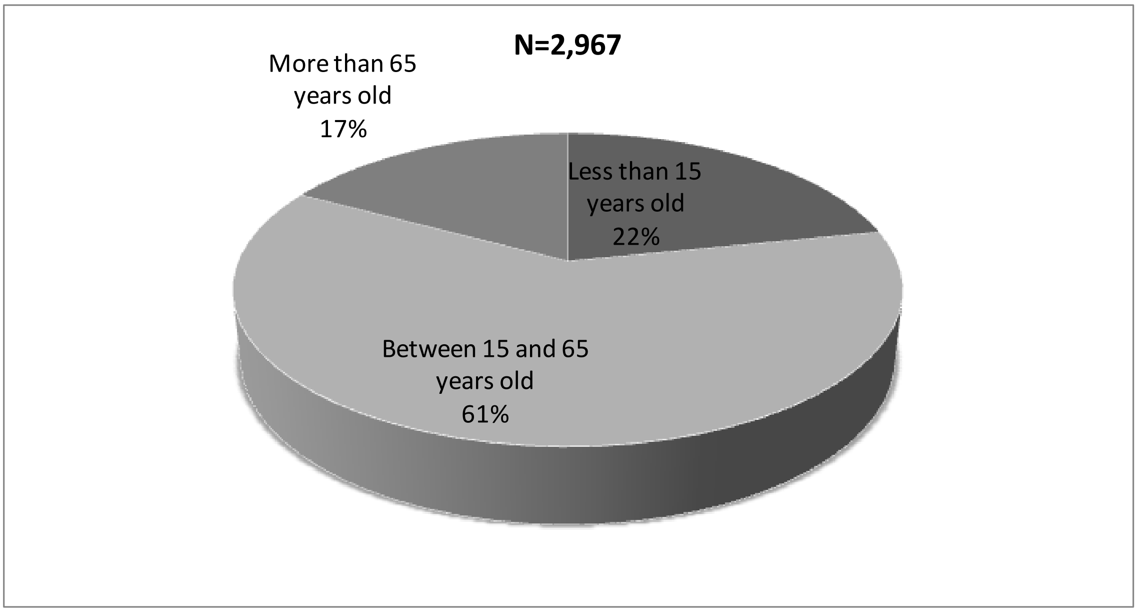
This town is regarded as the dormitory town of Toyama city. This town also has an accumulation of secondary industry, so that in the rate of composition of secondary industry is rather larger.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 45 Employees' industry structure in the village of Funahashi in 2010

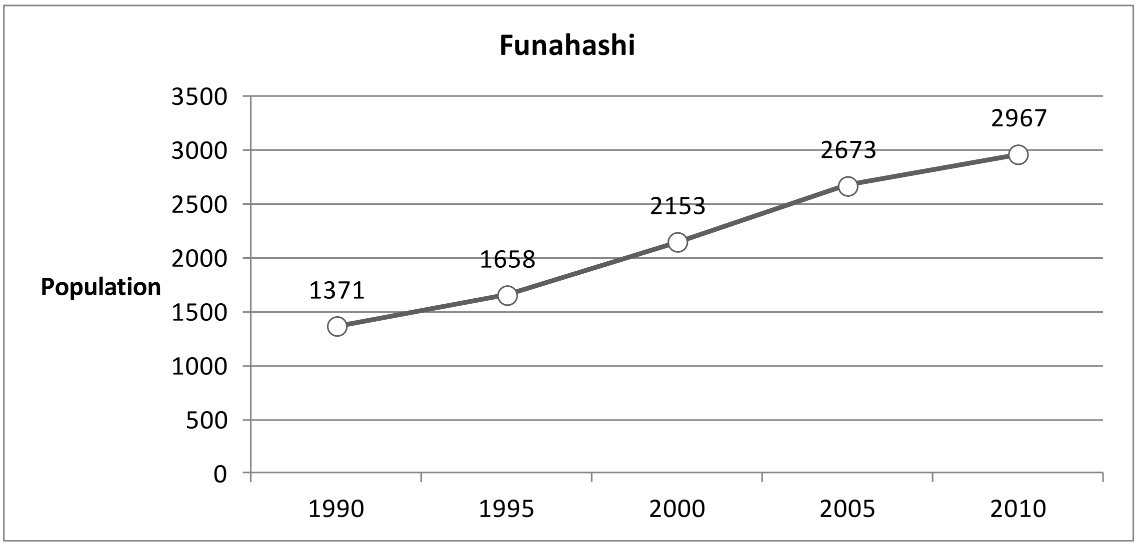
Because of increase in the young generation, the population composition is rather younger than the average of the whole nation.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 46 Age structure of population in the village of Funahashi in 2010

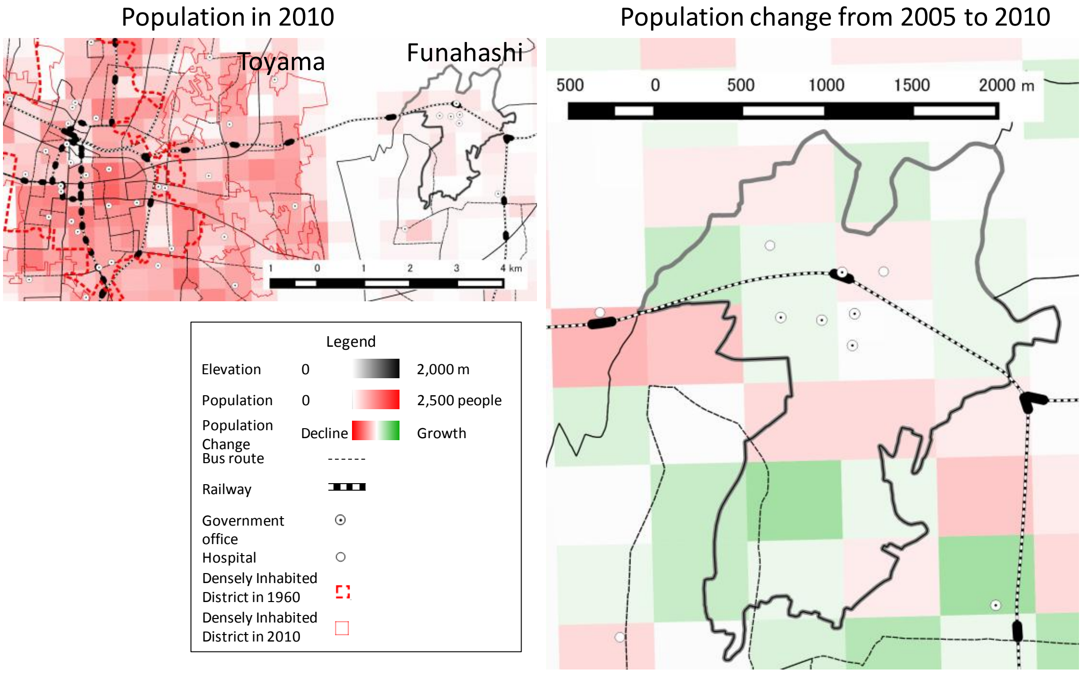
The population has been growing constantly in this period and has become more than twice as much as it was in 1990.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 47 Population trend in Funahashi between 1990 and 2010

The distribution of population seems to be along the railway line and bus route. The tendency of population increase is not necessarily following the tendency of population distribution.

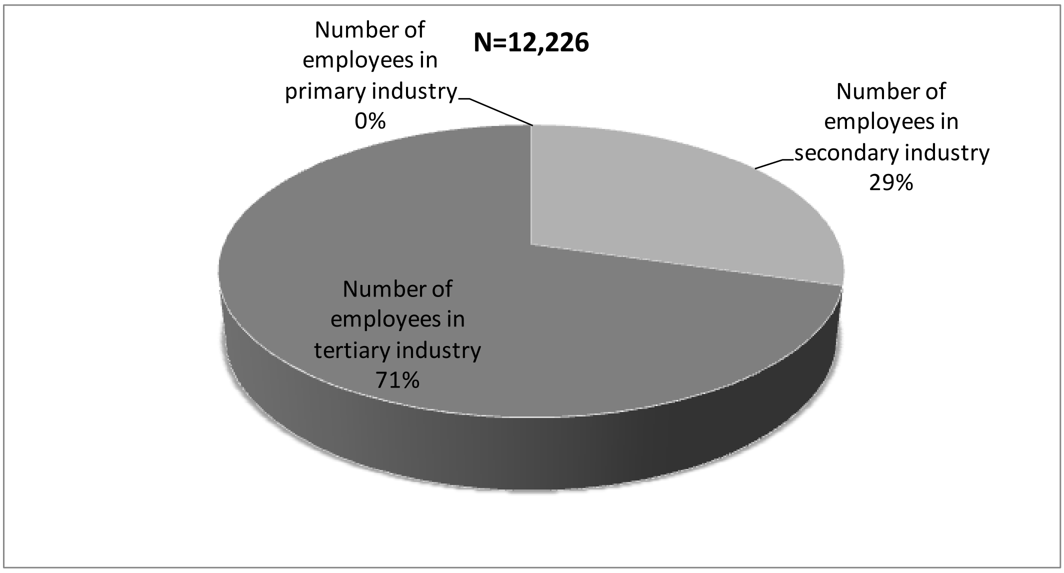


Source: National Land Numerical Information Data (City Areas (surface), Densely Inhabited District (surface), Elevation, Degree of Slope 5th Mesh Data, Medical Organization (point), Local Government Office, etc. and Public Meeting Facility (point), Railways (line), Bus route (line)).

Figure 48 Population distribution and population change in the village of Funahashi

3.3.4.3.2 Rifu

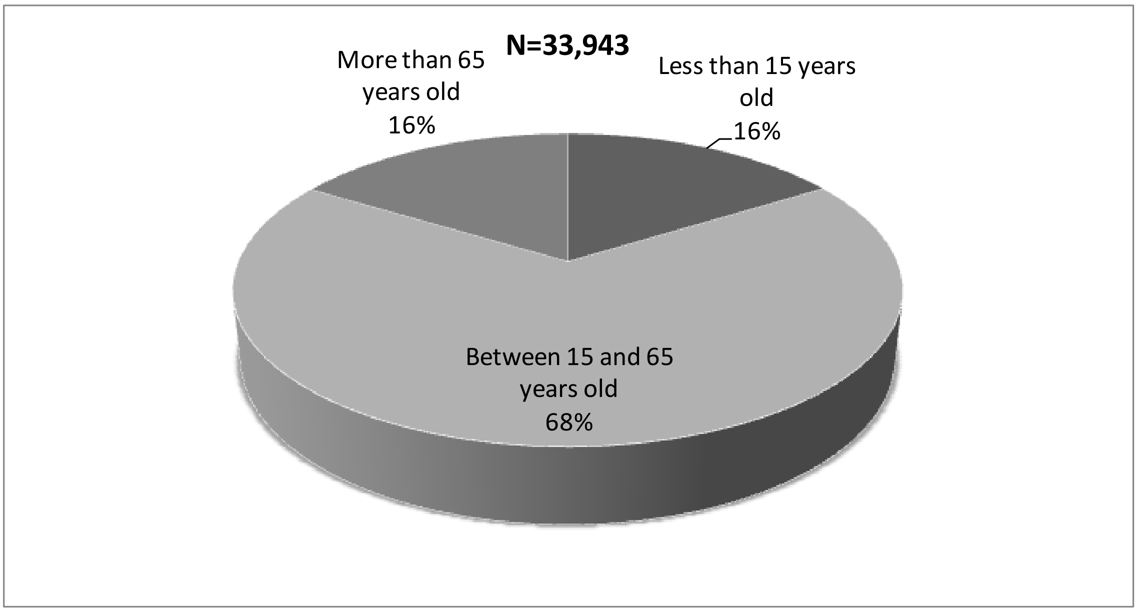
Rifu is also the dormitory town of Sendai, which is the prefectural capital and also regional centre of Tohoku region. Accordingly, the composition of the industry of employees living in this town almost completely belongs to the tertiary industry.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 49 Employees' industry structure in the village of Rifu in 2010

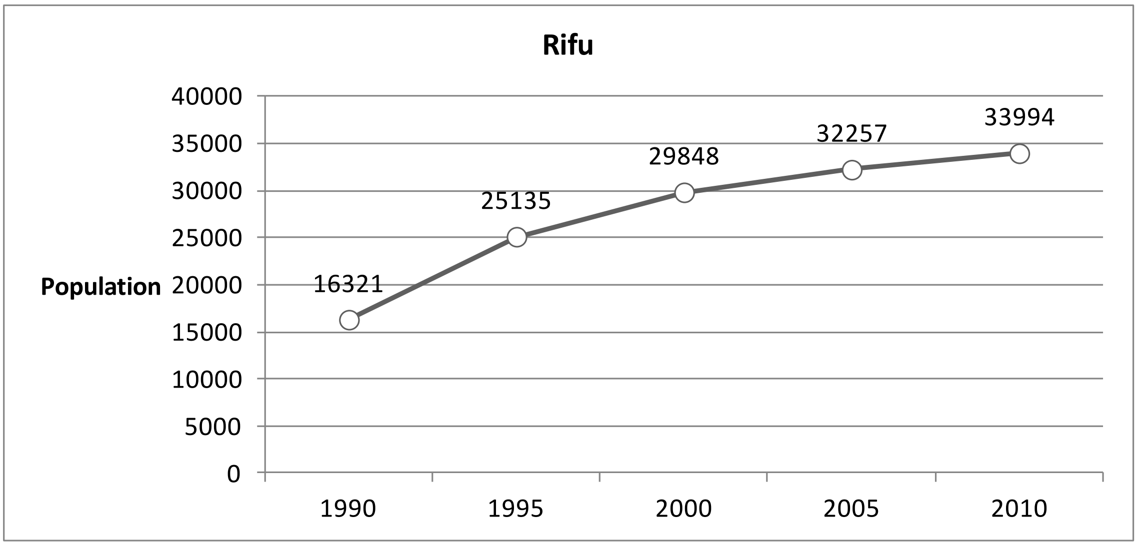
Age structure is also very young. In particular, the working age population is larger than other towns.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 50 Age structure of population in the village of Rifu in 2010

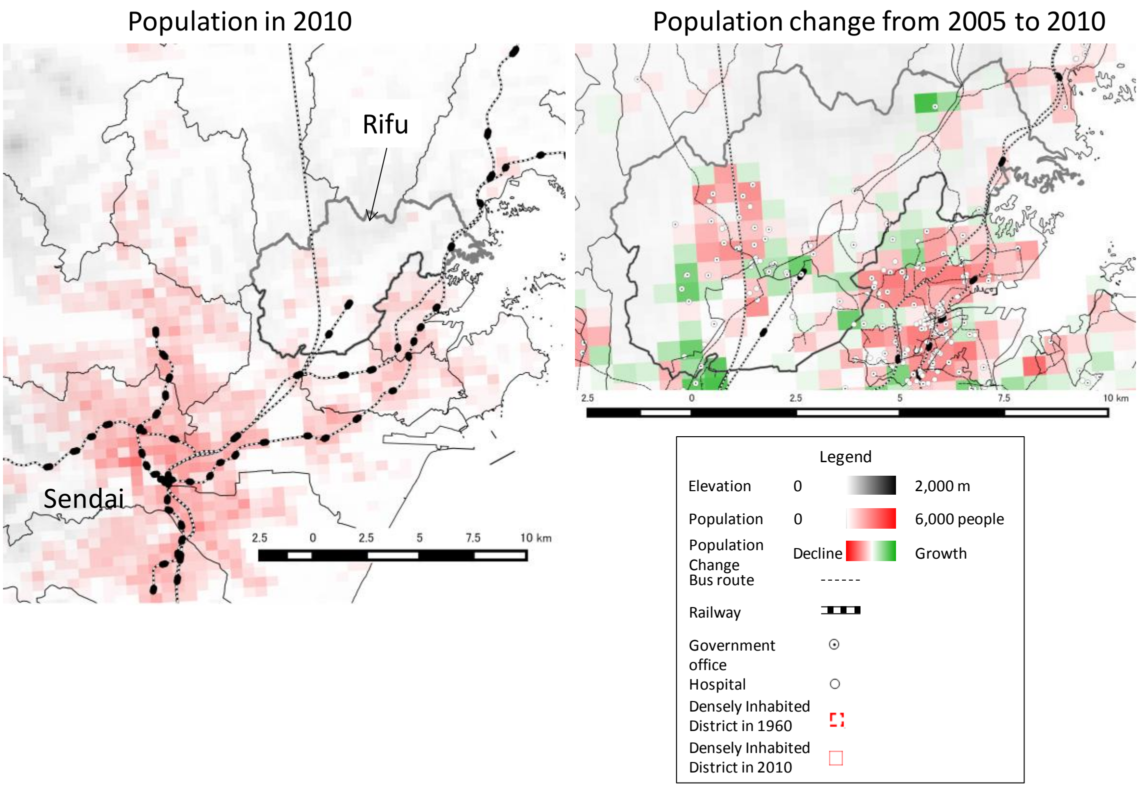
The population in the town has also been developing since 1990. In particular, the population growth between 1990 and 1995 was very rapid, but the speed of increase is gradually going down.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 51 Population trend in Rifu between 1990 and 2010

The town of Rifu also has hills, so population is mainly distributed in the plain area. The concentration of the population is not necessarily along the railway service. This town does not have any DID in 1960 or 2010, and the mesh of population increase is located on the edge of the populated areas. This suggests that somehow sprawling is also happening.

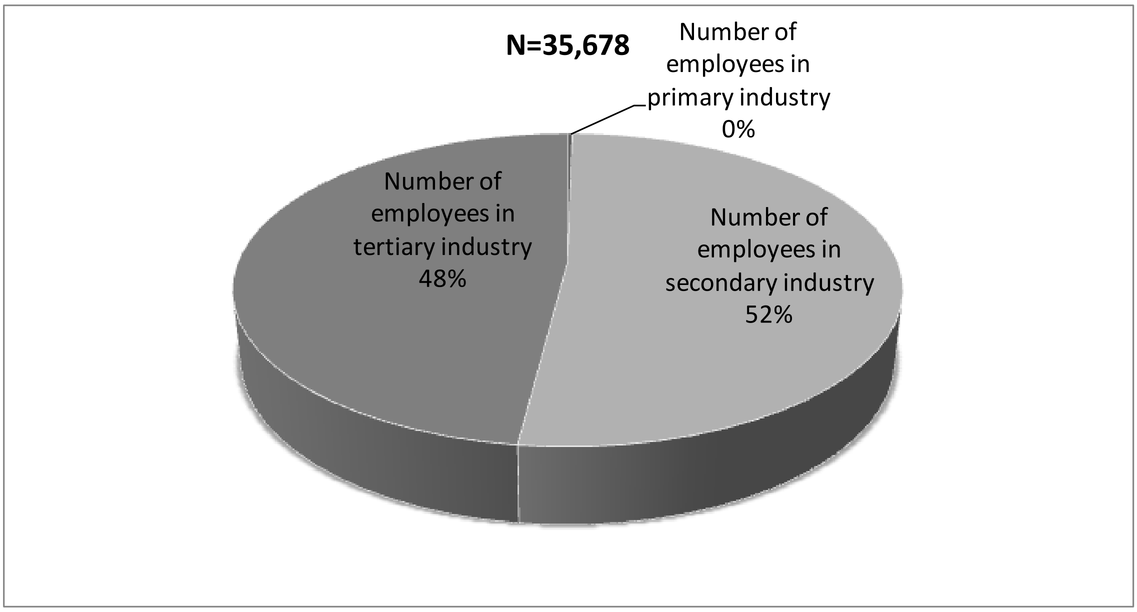


Source: National Land Numerical Information Data (City Areas (surface), Densely Inhabited District (surface), Elevation, Degree of Slope 5th Mesh Data, Medical Organization (point), Local Government Office, etc. and Public Meeting Facility (point), Railways (line), Bus route (line)).

Figure 52 Population distribution and population change in the city of Rifu

3.3.4.3.3 Miyoshi

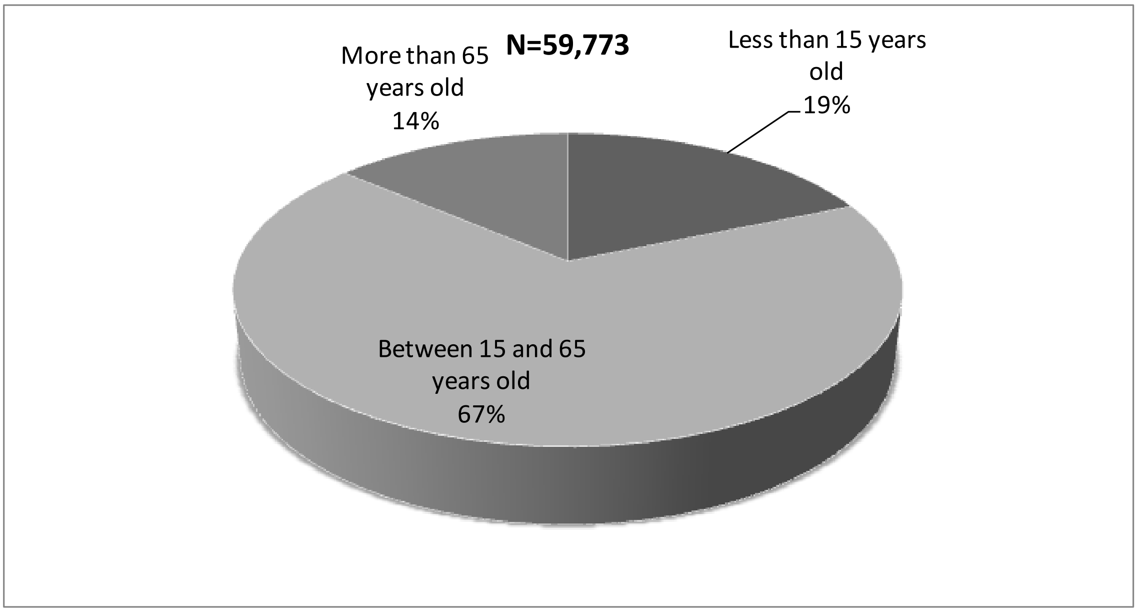
Miyoshi is located between the city of Nagoya and the city of Toyota. This is actually an industrialized area for the automobile industry in Japan. Also, Miyoshi is a dormitory town for both cities, because the distance from both cities is less than 10km. Those two factors affect the industrial composition of the number of employees in the city.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 53 Employees' industry structure in the village of Miyoshi in 2010

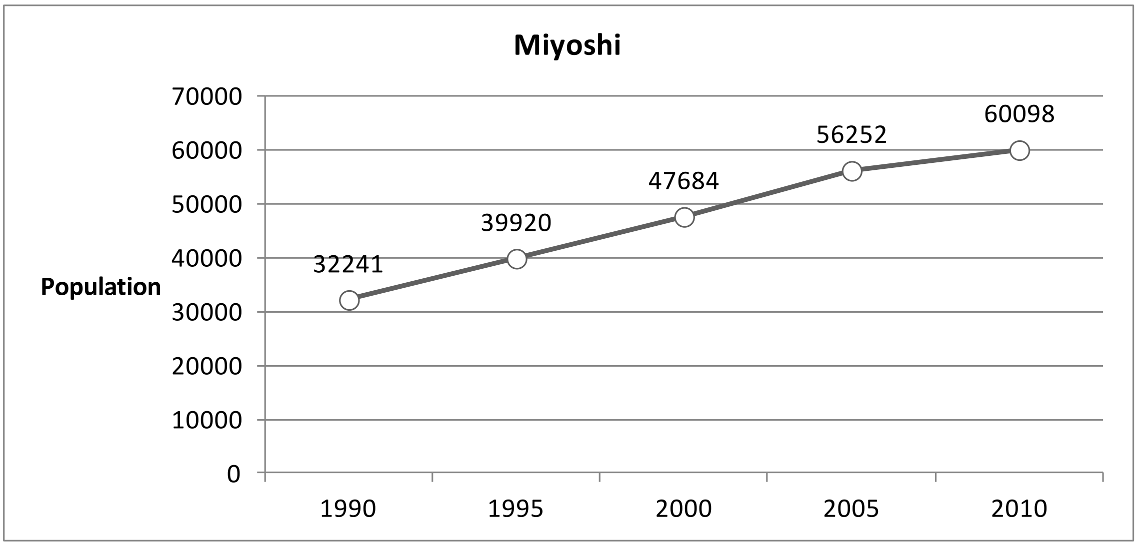
As a result of being a dormitory town, the age structure of this city is also rather younger than the average of the whole nation.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 54 Age structure of population in the village of Miyoshi in 2010

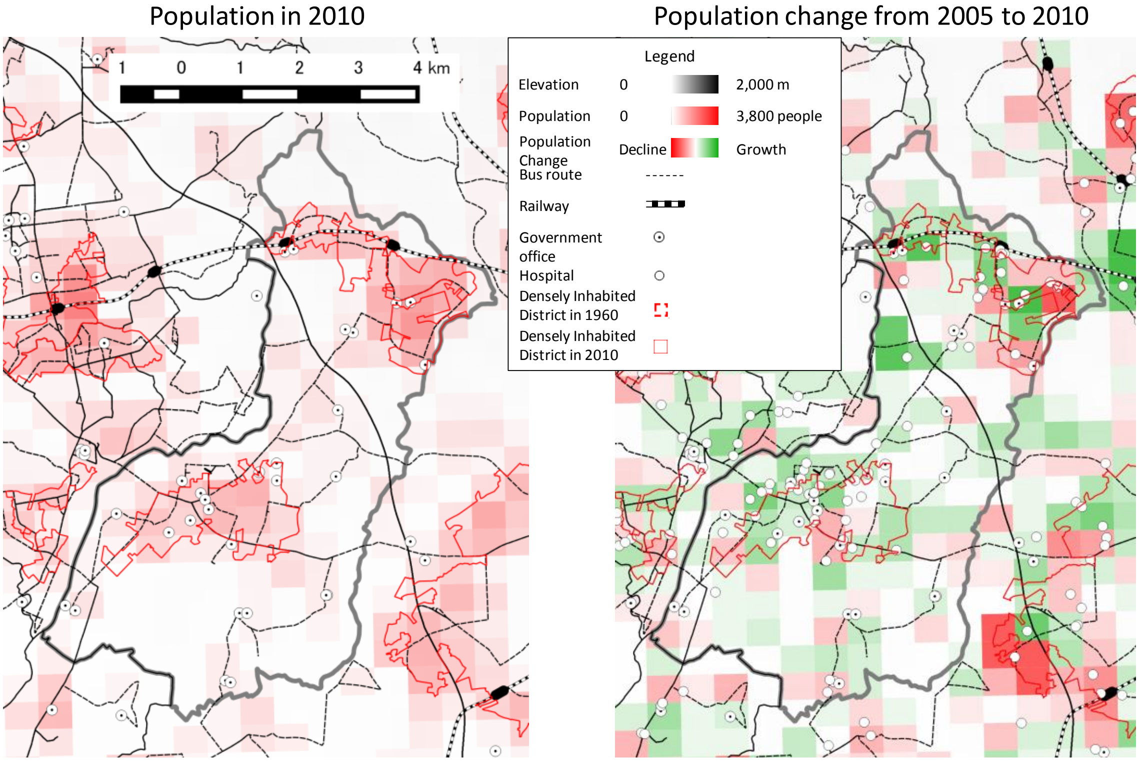
The population is growing in this period and has become almost twice as much as it was in 1990.



Source: Ministry of Internal Affairs and Communications (2011), National Census of Japan.

Figure 55 Population trend in Miyoshi between 1990 and 2010

The population accumulation is polarized, north along the railway and south along the bus route. Population increase is also observed in the populated areas but also in other areas. Some population increase is observed outside of DID in 2010, which also means some sprawling.



Source: National Land Numerical Information Data (City Areas (surface), Densely Inhabited District (surface), Elevation, Degree of Slope 5th Mesh Data, Medical Organization (point), Local Government Office, etc. and Public Meeting Facility (point), Railways (line), Bus route (line)).

Figure 56 Population distribution and population change in the city of Miyoshi

3.4. Discussion and Analysis

The tendencies of population change and other factors are as follows.

First, the less populated municipalities, which are often located in rural areas, tend to lose population more than urban municipalities. This trend is common in the prefectural level.

Second, the settlements are normally scattered over the municipalities, but the distribution of population in the settlement areas tend to be concentrated because of severe geographical constraints, in particular, in depopulating municipalities. On the other hand, the depopulating settlements in the plain areas or wide basin are gradually sprawling even now in some municipalities.

Third, the tendency of population change and the main industry of the municipality are not necessarily obviously correlated because a municipality’s most depopulating industry is tourism, but the main cause of population decline in Shimukappu is the decline in the farmers, in contrast with Shintomi, a municipality with stable population, where the main industry is primary.

Fourth, it is a little difficult to find the relation between population change and the location of infrastructure like railway stations, bus routes, hospitals and government offices. In municipalities like Funahashi and Shimukappu, the mesh next to the transport infrastructure of railway station and bus route may increase the population, but in Kohoku, it does not.

3.5. Concluding Remarks

In summary, it can be said that it is difficult to point out a concrete and confirmed tendency and relationship between population change and other factors. This chapter can shoow what happens to population change in typical areas selected according to the objective rules. These cases can illustrate actual various situations in Japanese population change. Accordingly, the relationship between population change and potential reasons should be examined more carefully in the future by increasing the number of samples, but that is a different research topic from this thesis.

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CHAPTER 4: THE HISTORY AND INSTITUTIONAL FRAMEWORK OF INFRASTRUCTURE DEVELOPMENT IN JAPAN

4.1 INTRODUCTION

In this chapter, an overview of the history, policy framework and finance of infrastructure development in Japan is provided. This is intended to help the reader understand the relevant background while current developments in infrastructures are discussed in the following chapters.

In terms of the policy framework of infrastructure development, the entities responsible for each type of infrastructure development are introduced, and then a long-term infrastructure development plan is presented. Also, a cross checking system between charged departments and planning/financing departments in municipalities is explained.

The history of infrastructure development follows, referring to investment data as well as stock amount data for each type of infrastructure. Also, the urban and rural accumulation of infrastructure stock is discussed. Projections of maintenance costs, replacement investment and new investment in the form of infrastructures supervised by the MLIT are also shown with reference to the historical data. These results suggest that the critical situation of infrastructure management will not appear soon.

Finally, the financing of infrastructure development is discussed. Tax, user charges, T-bonds, local bonds and PFI can be considered as forms of general finance for infrastructure development and management, but financing tools other than tax and user charges should be reimbursed in the future. Thus, tax revenue can be regarded as the main form of infrastructure financing for municipal and prefectural infrastructure development.

4.2. METHODOLOGY

4.2.1 LITERATURE REVIEW

Local government financing systems, local support tax systems, the history of infrastructure development, the projection of maintenance and replacement costs for elements of infrastructure are among the topics discussed in the existing books and reports published by the government as well as by related non-profit organisations. In this study, the following works are used in the literature review.

Table 17 Literature on history of and financing system for infrastructure development and management

Topics	Literature
Local government financing system	Council of Local Authorities for International Relations (CLAIR) (2013)
Local allocation tax system	Chiho Kohuzei Seido Kenkyukai ed. (2013a) Chiho Kohuzei Seido Kenkyukai ed. (2013b)
History of infrastructure development and management	Director General for Economic, Fiscal and Social Structure (2007)
Projection of maintenance cost and replacement investment on infrastructure	Ministry of Land, Infrastructure, Transportation and Tourism (2011)

4.2.2 EXPERT INTERVIEWS

The literature review has limitations in terms of collecting practical knowledge about policies. Some expert interviews are, therefore, conducted for the Ministry of Internal Affairs and Telecommunication (MIC), and the Ministry of Land, Infrastructure, Transport and Tourism as follows;

Table 18 Interviewees and questions

Interviewees	Date	Questions
Director of grant-in-aid division, Department of Local Finance, Ministry of Internal Affairs and Telecommunication	23rd July, 2014	· Policy system of grant-in-aid from local allocation taxes · How to calculate the unit cost in the formula · Others
Officer, Department of Roads, Ministry of Land, Infrastructure, Transport and Tourism	16th July, 2014	· Policy on comprehensive grants for infrastructure development and grants for anti-disaster and safety · Others

4.3 Results

4.3.1 Current policy system for infrastructure development

4.3.1.1 Authorities on infrastructure development

Table 19 shows some long term plans for infrastructure development. These plans include the targets and challenges of infrastructure development and management for central government, prefectural and municipal government.

The third infrastructure development priority policy programme (31st August 2012, Cabinet decision) decided on the four major priority targets including anti-disaster countermeasures and countermeasures against the deterioration of infrastructure (Ministry of Finance, 2014).

Table 20 shows the development entities of types of infrastructure. The table shows that most of infrastructure in the national Natural Park is developed by municipalities. Also, solid waste management from industry and telecommunication infrastructure is only developed by private companies.

Table 19 Major infrastructure development plan and law in Japan

Plan	Law	Contents	Sector
Priority Plan for Social Infrastructure Development (2012-2016)	Act on Priority Plan for Social Infrastructure Development	Prioritised targets of infrastructure development and project outline of infrastructure development to achieving these targets	Road, traffic safety, urban park, waste water management, port, flood control, airport, land slide prevention, coastal protection, railway and air traffic control
Waste disposal facility development plan (2013-2017)	Waste Management and Public Cleansing Act	Targets and outline of solid waste management facilities development projects	Waste management facility
Land improvement long-term plan (2012-2016)	Land improvement act	Targets and business amount of land improvement	Land improvement
Fishing port fishing place maintenance long-term plan (2012-2016)	Act on Development of Fishing Ports and Grounds	Targets and business amount of fishery port and fishery place development	Fishing port, fishing place
Forest development and management business plan (2009-2013)	The forest act	Targets and business amount of forest development and management	Forest development and management Land slide prevention
Basic plan for housing (2011-2030)	Basic Act for Housing	Targets of securing and improving housing and basic policies to achieve the targets	Public housing

Source: Ichikawa (2013), p.150.

Table 20 Responsible entities of infrastructure development

Category	Sub category	Type of infrastructure	Authority of Infrastructure development				
			Nation	Prefecture	Municipality		Others
					ordinance-designated city	Others	
Road	General road	National highway	○	○	○		
		Prefectural highway		○	○		
		Municipality roads			○	○	
	Toll road						Highway corporation, local highway corporation
Port	Port		○	○	○	○	Port authority
Aviation	Airport		○	○	(○)	○	Narita International Airport Corporation, Kansai International Airport Co., Ltd., Central Japan International Airport Co., Ltd.
Railway	Railway				○	○	Private companies, The public private partnership company, Japan Railway Construction, Transport and Technology Agency
Public housing	Public housing	Public housing		○	○	○	
		subsidised rental apartment with high quality		○	○	○	
Water supply	Water supply				○	○	
Waste water management	Waste water management			○	○	○	
Solid waste management	Solid waste management	Household waste management			○	○	
		Industrial waste management					○

Urban park	Urban park	Municipality park		○	○	○	
		National park	○				
Education	School (Elementary, Junior high school, high school, University, technical college, kindergarten		○	○	○	○	incorporated educational institution, National University Corporation, etc.
Flood control	River	First class river	○	○	○		
		Second class river		○	○		
		Small river			○	○	
	Sand protection		○	○	○	○	
Land slide prevention	Land slide prevention		○	○			
Coast protection	Coast protection		○	○	○	○	
Agriculture, forestry and fishery	Agriculture		○	○	○	○	Land improvement districts
	Forestry roads		○	○	○	○	
	Fishery port and fishing place		○	○	○	○	
Social welfare	Health care facility	Health centre		○	○		
		Hospital	○	○	○	○	Medical corporation
	Social care facility		○	○	○	○	Social welfare corporation
Electricity and telecommunicatio n	Electricity and telecommunication						Private company
Gas	Gas				○	○	Private company
Natural park	Natural park	National park	○				
		Quasi-national park		○			
		Prefectural natural park		○			

Source: Editing Director General for Economic, Fiscal and Social Structure (2012), p.15 and addition of gas column by the author

4.3.1.2 Governance of infrastructure development and management

The topic of the governance of infrastructure development and management in government bodies will now be introduced.

On a national level, the MLIT develops and manages roads, rivers (flood control and water resource development), urban infrastructure (park, waste water management), ports, airports and air-control, railways, coast protection and public housing. The Ministry of Agriculture, Forest and Fishery develops irrigation, agricultural field development, forest management, roads, fishery ports and fishing places. The Ministry of Education, Culture, Sports, Science and Technology supports the development of schools and social education facilities. MIC supervises telecommunication and postal services. The Ministry of Economy, Trade and Industry regulates the energy companies to develop and manage energy infrastructures like electricity and gas. In this way, in Japan, different ministries develop a national level of infrastructure and also support and supervise municipalities and private companies in order to develop local infrastructure and manage infrastructures, including those at national level one, based on their own respective responsibilities. Each ministry also develops a policy and regulatory framework for their infrastructure sector and a draft budget. On the other hand, the Ministry of Finance reviews the draft of a budget created by each ministry and adjusts it according to the policy on budget-making of the government of the time.

A similar system can be observed in local government. The main responsible department of infrastructure development includes the civil engineering and industry departments. On the other hand, the financial department (through a finance clerk) manages the financing of infrastructure development and management while the planning division (through a planning promotion clerk) summarises a long-term development and management plan for each element of the infrastructure handled by each department.

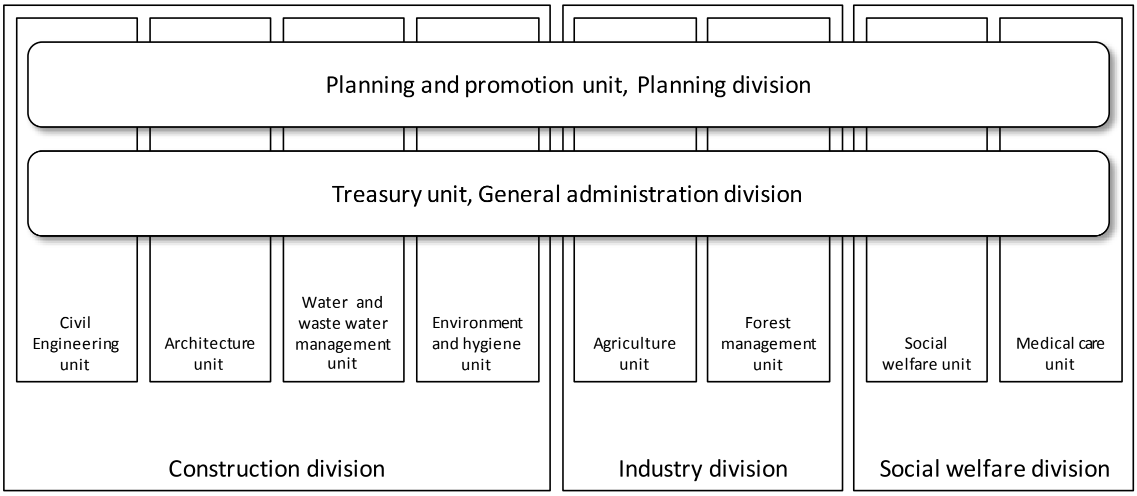


Figure 57 Demarcation of internal divisions and units in infrastructure development and management in the town of Minamifurano

Table 21 Departmental responsibility in the town of Minamifurano

Department	Sub-department	Scope of work	Infrastructure manager
Mayor and Vice Mayor / Administration Division	General affairs clerk	Acts as secretary to mayor and vice mayor, responsible for receipt and issue of public documents, conferment, commendations, promulgation of the ordinance regulations, salary payments, social welfare and pensions for government officers, training of government officers, management of public building and equipments, administration reform, disclosure of government activities, consumer information protection and management of business trips for officers.	
	Finance clerk	Budget and budget closing of the town	
	Anti-disaster clerk	Crime control, road safety, anti-disaster management, countermeasures to reduce harm	
	Tax clerk	Residential tax, property tax, light-automobile tax, national health insurance tax, issuing number plates for automobiles, collection of tax	
	Family register pension clerk	Family register, residential registration, seal registration, cremation-burial permit, national pension, various certification, and so on	
Election Commission Secretariat		Matters of election	
Accounts Division	Treasurer	Receipt and payment of public money	
Parliament and of the Audit Committee Secretariat		Parliament and audit matters	
Planning Division	Planning promotion clerk	Comprehensive plan, regional promotion and town development, international exchange, immigration, hometown assembly, merging municipalities, regional united administration, homepage matters, local informatics, land use plans, management of town-owned properties	
	Public statistics clerk	Issues of public communication, town administration handbook, movable mayor office, letter to mayor, statistics	
Health and Welfare Division	Social welfare clerk	Welfare of single parent families, human rights protection, support for disabled, children's welfare, financial support for children, management of welfare facility, children's club, nursery facilities and so on	○
	Care medical clerk	Care insurance, national health insurance, insurance for the elderly, financial aid with medical payments and hospitals	○

	Health guidance clerk	Various medical checkup, mother-child care, health consultation, physical function training, visiting consultation	
Industry Division	Agricultural administration clerk	Farm management, promotion of agricultural products, finance for agriculture, promotion of animal husbandry, land improvement, elderly person training.	○
	Forest management clerk	Management of town forests, prevention of wildfire, promotion of forestry association, extermination of harmful deer and bear, development and maintenance of forestry road, permission for forest entry, conservation of forests and promotion of forestry	○
	Commerce and tourism clerk	Promotion of commerce and industry, labour issues, consumer protection, tourism promotion, management of tourism facilities and so on	
Agricultural Committee Secretariat		Consultation of agricultural field, pensions of farmers.	
Construction Division	Civil engineering clerk	Development and improvement of roads, rivers, bridges, issues of occupied permission of roads and rivers, tendering civil works and contracts, operation of municipal bus services, street light management	○
	Architecture clerk	Construction policy, supervision of construction and improvement, public housing management, collecting tenant fee of public housing and so on.	○
	Water supply and sewerage clerk	Development and management of water supply facilities, collection of water charge, development and management of waste water management facilities, collection of sanitation charges	○
	Environment and hygiene clerk	Household origin gavages collecting and treatment, sanitation, bee extermination, dog registration, pollution control, hygiene, septic tank construction and abolition, cemetery management and funeral hall management	○
Board of Education		School education, lifelong learning, social physical education	○

Source: Web site for the town of Minami Furano

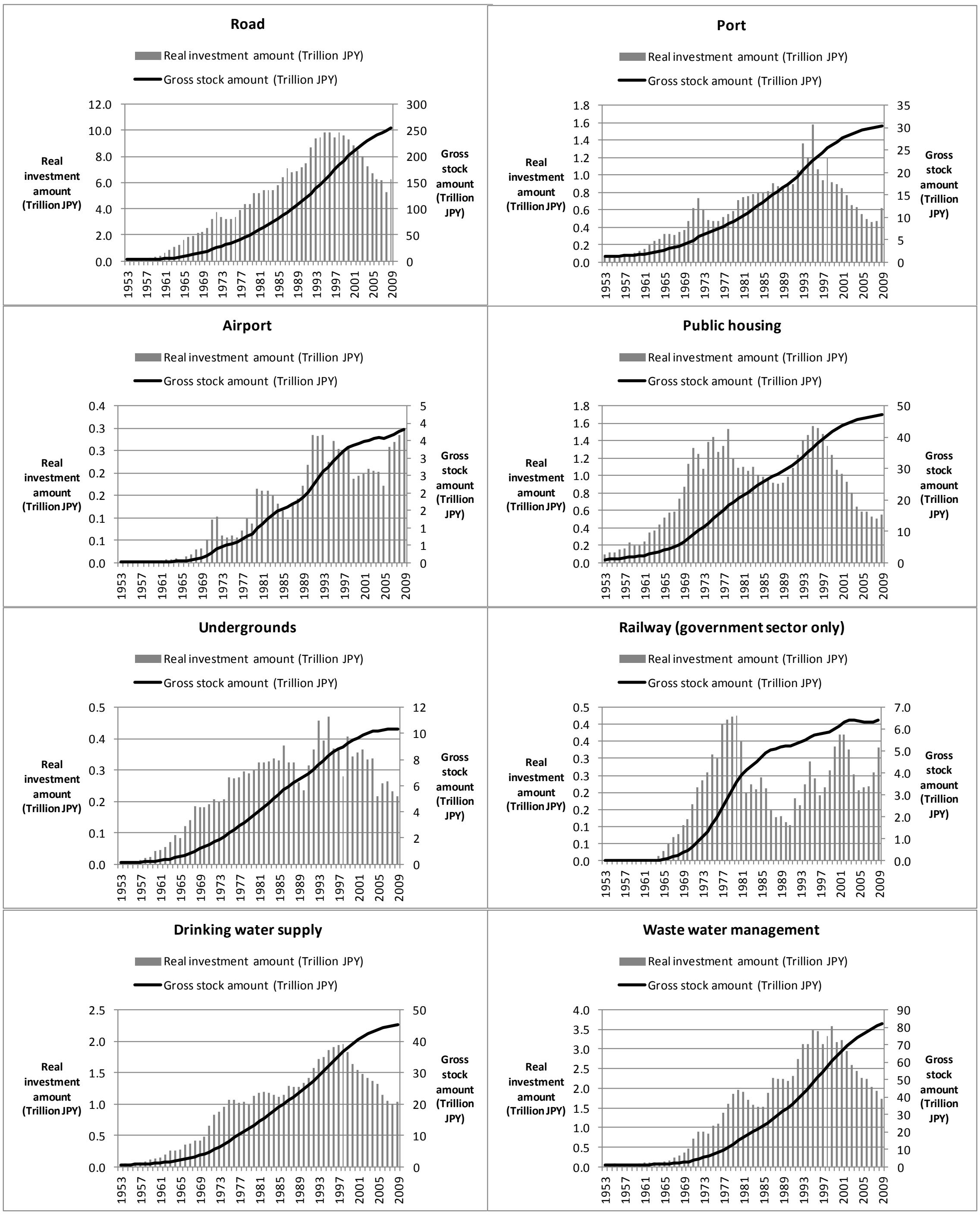
4.3.2 *DEVELOPMENT HISTORY OF THE INFRASTRUCTURE IN JAPAN*

In Japan, infrastructure development was restarted after World War II and has continued. The peak of the investment in each type of infrastructure is different. For example, the 1970s was the first peak in the development of railways and public housing. 75% of the stocks for the subway had been accumulated by 1994. On the other hand, waste water management and solid waste management facilities' development followed other types of infrastructure development, while 25% of stock formation of those infrastructure types occurred in 1984 and 1987 respectively. 75% of the stock formation had accumulated by 2000. After the collapse of the Bubble Economy, infrastructure development for revitalizing economy was speeded up. The peaks of infrastructure investments occurred, therefore, in 1990s. On the other hand, fiscal reconstruction since 1998 has not allowed the increase in infrastructure investment. The investment for all types of infrastructure but airports and schools excluded replacements due to ageing deterioration or aggregation and relocation has been declined since 1998 because of constraining infrastructure development before population decline began.

Table 22 Peak of investment and stock formation of infrastructure in Japan

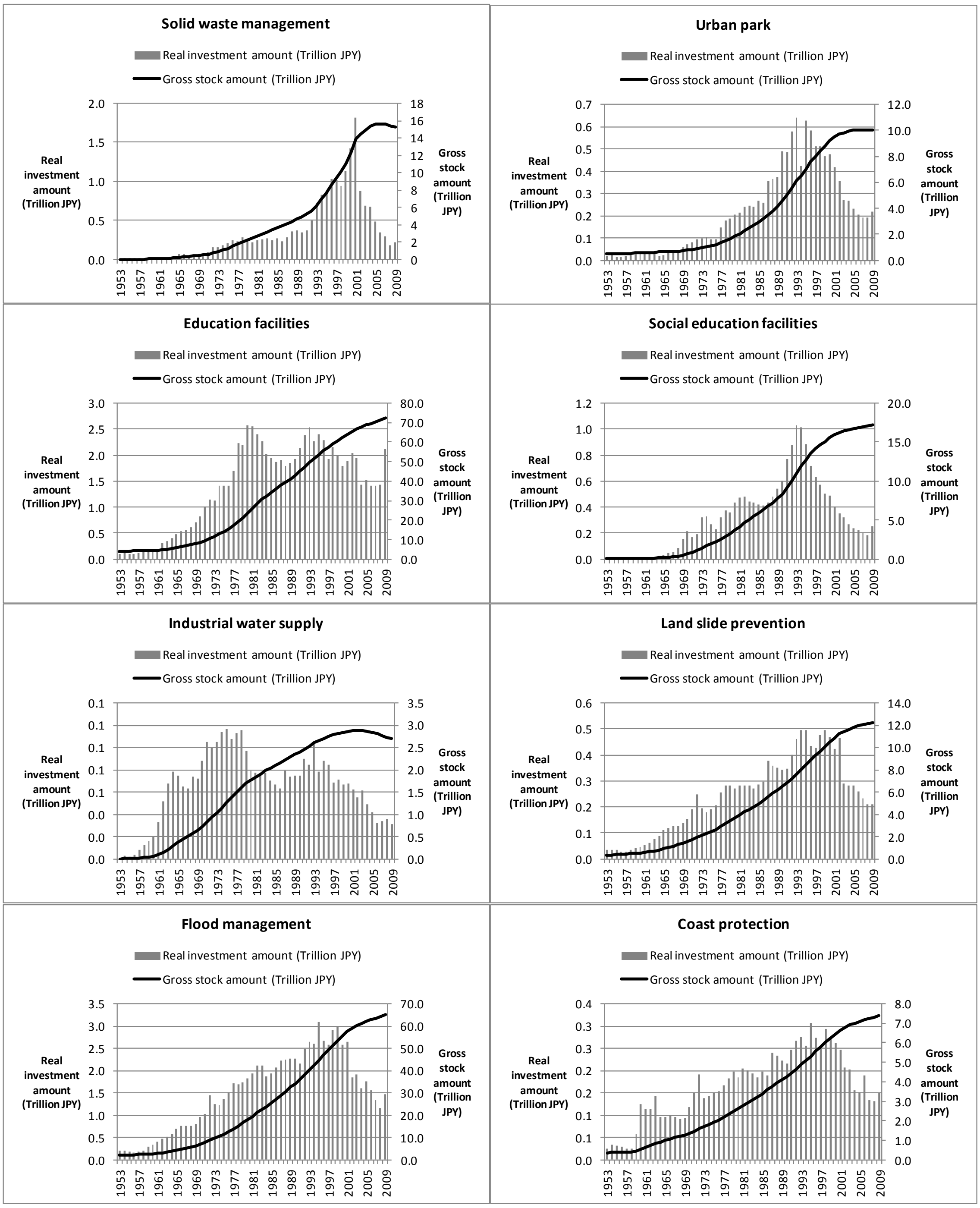
Type of infrastructure	Year of investment flow	Stock formation		
		25%	50%	75%
Road	1990s	1982	1992	1999
Port	1990s	1977	1988	1996
Airport	1990s and latter half of 2000s	1980	1990	1995
Railway	1970s and around 2000	1975	1980	1986
Subways	1990s	1976	1985	1994
Public housing	1970s and 1990s	1974	1984	1995
Waste water management	1990s	1984	1993	2000
Solid waste management	the latter half of 1990s	1987	1996	2000
Water supply	1990s	1978	1989	1997
Urban park	1990s	1984	1991	1996
School	1980s and 1990s	1978	1987	1996
Social Education	1990s	1982	1991	1996
Flood management	1990s	1979	1989	1997
Land slide prevention	1990s	1978	1989	1997
Coast protection	1990s	1975	1987	1996

Source: Director General for Economic, Fiscal and Social Structure (2012)



Source: Director General for Economic, Fiscal and Social Structure (2012)

Figure 58 History of infrastructure development in Japan (1)



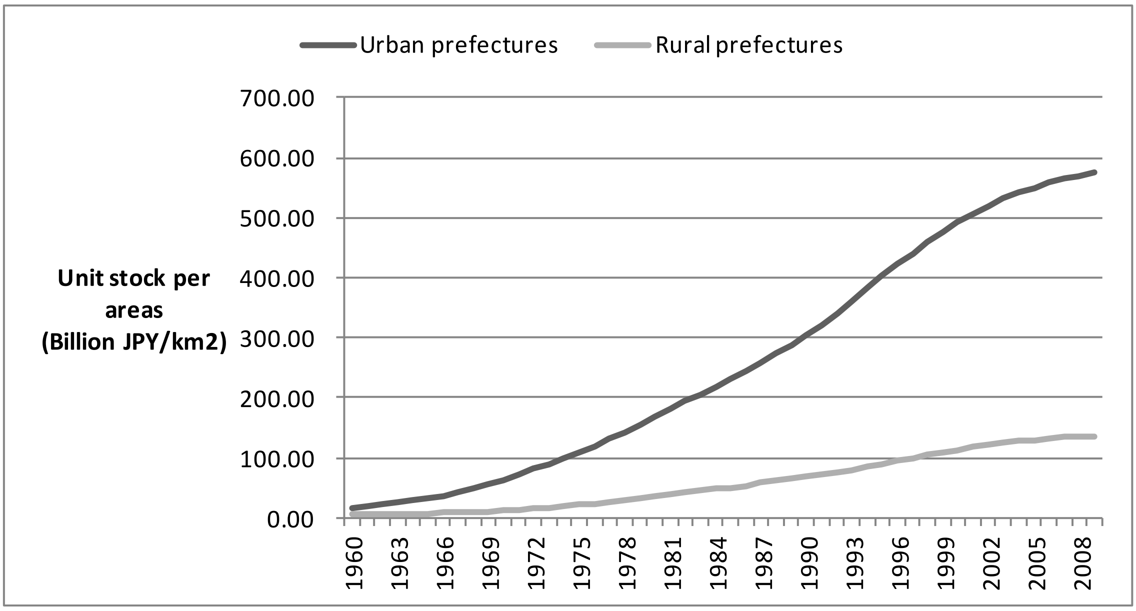
Source: Director General for Economic, Fiscal and Social Structure (2012)

Figure 59 History of infrastructure development in Japan (2)

4.3.3 GEOGRAPHICAL TRANSITION OF INFRASTRUCTURE DEVELOPMENT

Differences in the accumulation of infrastructure investment per unit areas (Km^2) in 15 types of infrastructure are examined here. These types are roads, ports, airports, railways, subways, public housings, waste water management, solid waste management, water supplies, urban parks, schools, social education, flood control, land slide prevention and coast protection, between urban prefectures and rural prefectures. 12 prefectures, including three major metropolitan areas and the regional cores of Tohoku and Kyusyu, namely Miyagi, Saitama, Chiba, Tokyo, Kanagawa, Shizuoka, Aichi, Kyoto, Osaka, Hyogo, Nara and Fukuoka are defined as urban prefectures. On the other hand, the rest of the 35 prefectures are defined as rural prefectures.

As the result of the calculation of the accumulation of infrastructure investment per area (JPY/km^2) in 2009, the average accumulation of infrastructure in urban prefectures was 4.23 times as much as that in rural prefectures. Accordingly, it can be concluded that, generally speaking, urban areas require more infrastructure than rural areas.



Note: Urban prefecture: Miyagi, Saitama, Chiba, Tokyo, Kanagawa, Shizuoka, Aichi, Kyoto, Osaka, Hyogo, Nara and Fukuoka

Source: Director General for Economic, Fiscal and Social Structure (2012)

Figure 60 Infrastructure stock accumulation per areas in between urban prefectures and rural prefectures

4.3.4 Official projection of maintenance and replacement cost of infrastructure development

Next, Figure 61 shows the projection of infrastructure maintenance costs and replacement investment in 2011 (Ministry of Land, Infrastructure, Transport and Tourism, 2011)[1]. The total of projected maintenance costs and replacement investment will exceed the 2011 to 2038 budgets. With regard to maintenance and replacement of infrastructure in 2040 because of insufficient financial resources, the Ministry of Finance and MLIT are currently engaged in a tug-of-war on the new investment for the infrastructure development with management because the total of maintenance cost and replacement investment is smaller than the total budget for infrastructure.

The MLIT, therefore, promotes an extension of the durability of infrastructure and flexibility of decision making of the priority of maintenance and replacement works to reduce the maintenance cost and replacement investment per annum and in order to secure the amount of new investment (Interview to MLIT).

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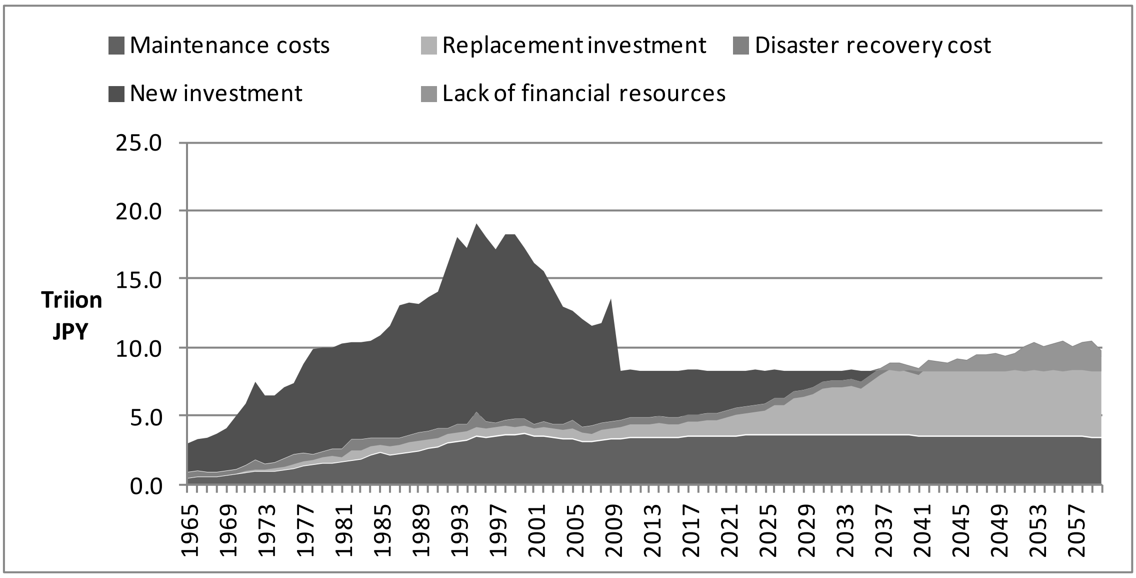
[1] Note: Method of maintenance cost and replacement investment projection
In targeting national direct development, it is necessary to consider local direct development and subsidies from central to local development of eight sectors of road excluding national highways owned by the national highway corporation, ports, airports, public housing, waste water management, urban parks, flood control and coastal management after 2011
Replacement investment: This can be used provided that the replacement is put in place immediately after the durable years have passed with the same feature, and when the amount of replacement is equal to the amount of previous new investment. Also a durable year is set based on the Finance Ministry ordinance representing the durable year for tax payment, as well as actual period until replacement.
Maintenance costs are projected based on the correlation between maintenance cost and stock mount for each type. It is noted that the projected replacement investment and maintenance costs are reflected by the policy of the cost reduction on infrastructure development and management after 1998.
Disaster recovery cost is assumed as the annual average of it.
New investment is calculated by deducting maintenance costs from the total amount, replacement investment and disaster recovery costs. This does not indicate a demand for new investment. New investment is not included in the land costs and compensation costs.



Source: Ministry of Land, Infrastructure, Transportation and Tourism (2011), http://www.mlit.go.jp/hakusyo/mlit/h23/hakusho/h24/html/n1216000.html (available on 20th July, 2014).

Figure 61 Estimation of results of maintenance costs, replacement investment, disaster recovery costs, new investment and a lack of financial resources

4.3.5 Finance for Infrastructure Development and Management

The financial resources of infrastructure development and management consist mainly of tax revenues, government bonds, fiscal investments and loans and user charge. Government bonds and fiscal investments and loans will be reimbursed by tax revenues and user charges. A user charge is a payment by a beneficiary, so that tax revenue is only considered to be a financial source for infrastructure development and management because of its unclear relationship to infrastructure development and management.

The financial resources for infrastructure development and management in local governments are basically expenditures from the general account, except for the special account for state-own enterprises. Previously, some of the tax revenue from fuel consumption was used specially for the road development and management, but after 2009, those special funding systems for infrastructure development were abolished.

A few subsidies from central government to local government still exist. First there is a comprehensive subsidy for infrastructure development. This is a transfer from central government to local government with regard to the comprehensive plan of infrastructure development and management made by local government. This subsidy was reorganized from previous subsidies for infrastructure development and management of each type. The upper limit of the subsidised ratio follows the ratio of central government responsibility regulated in each development act, when the amount is calculated (Ministry of Land, Infrastructure, Transport and Tourism, 2014).

Apart from the subsidy and transfer funds for general accounts of the central government, the other financial resources should be funded from the budgets of local government. For this amount, there are some parameters which consider the amount of infrastructure in local government to calculate the amount of supplemental financing in the local transfer tax amount between the necessary budget and independent revenue sources of local government (Chiho Kohuzei, Seido Kenkyukai eds., 2013a). The local allocation tax is a general account financial source, and is not directly linking to the maintenance work of infrastructure (CLEAR, 2012). It is, however, functioning enough to maintain the infrastructure in case enough of the budget is prepared for infrastructure management when the amount of local allocation tax is calculated from the perspective of budget control.

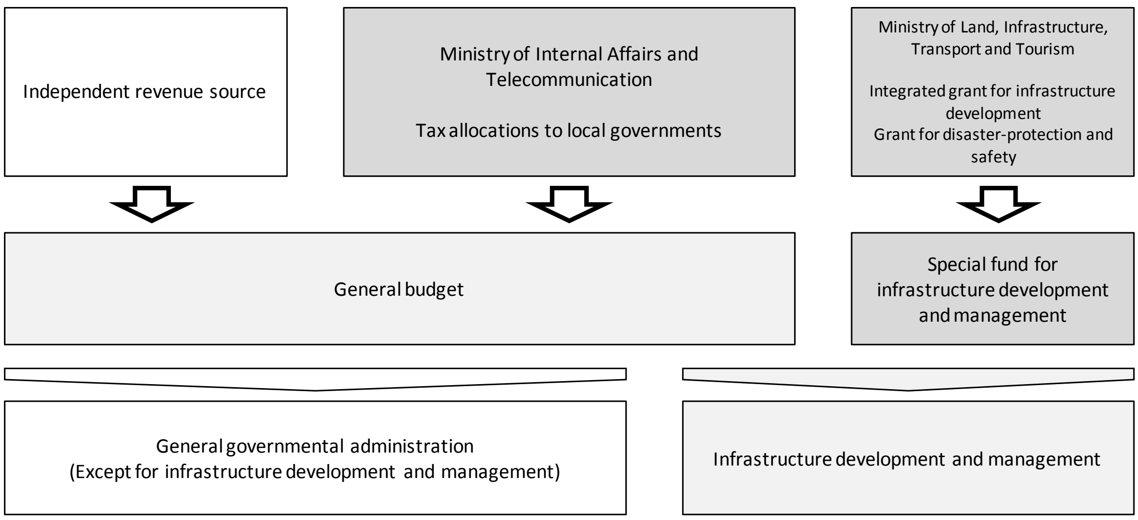
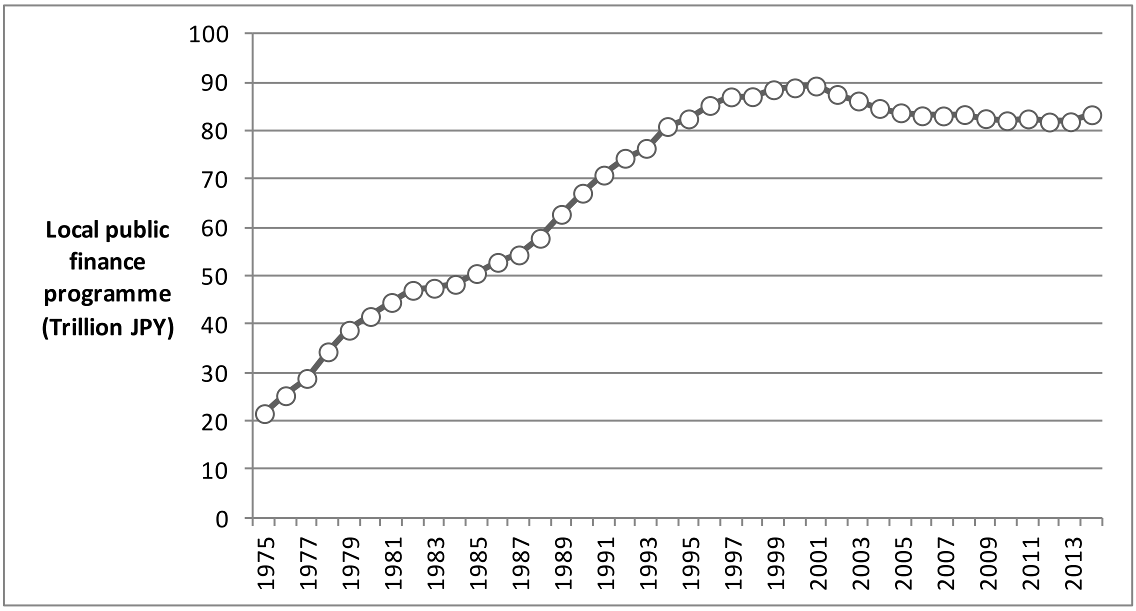


Figure 62 Financial streaming from central government to local government (mainly for infrastructures supervised by the MLIT)

In this way the comprehensive subsidies for infrastructure development and management and local allocation tax can be examined. For the former, how to control the differences between demands for it from local governments and central government budget constraints needs to be discussed, and for the latter, how to calculate the standardized transfer amount considering infrastructure amount should be also examined.

4.3.5.1 Local allocation tax (MIC)

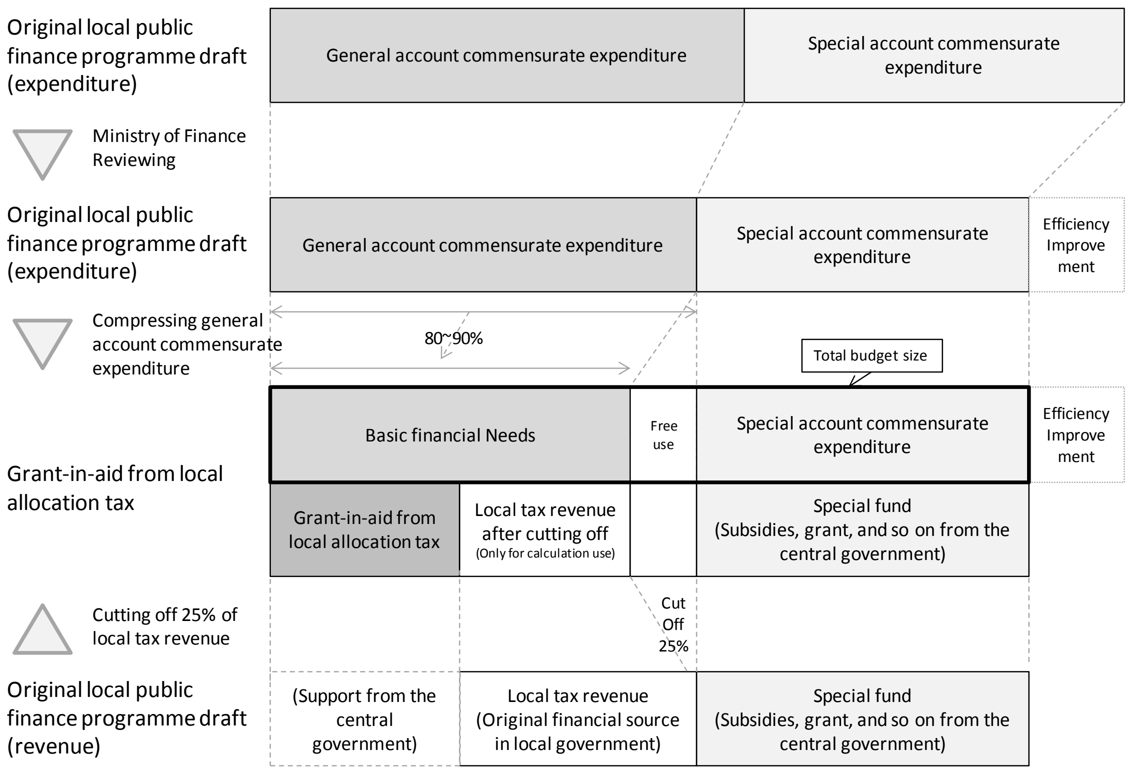
In the calculation of grant in aid from local allocation tax , a local public finance programme is firstly developed based on the closing of the account two years ago, the policy priority in the year, wholesale price index changes, demographic change and changes in the infrastructure, as reviewed by the Ministry of Finance. Figure 63 shows the trend of total budgets for local public finance programmes. The amount has been nearly stable for 20 years.



Source: Ministry of Internal Affairs and Telecommunication (2014)

Figure 63 Trend of the total budget of local public finance programme

The part of the local public finance programme amount deducted from both special fund amounts (subsidies and grant from central government) and local tax revenue is, secondly, estimated as the budget amount of grant-in-aid from local allocation tax. It is noted that the later introduced a comprehensive grant for the infrastructure development and management as well as a grant for the anti-disaster and safety issues, which are regarded as special funds in general and which are deducted from the amount of grant-in-aid from local allocation tax. The portion resulting from the Ministry of Finance’s reviewing is considered to be a part of the improvements in the efficiency of public expenditure. Furthermore, only 75% of local tax revenue are taken into consideration as the financial source for the grant-in-aid from local allocation tax, so that only around 80%~90% of the general account commensurate to expenditure in the original amount of local public finance programmes is regarded as a basic financial need in local governments.



Source: Interview results to the MIC

Figure 64 Image of calculation method of Grant-in-aid from local allocation tax in Japan

Interestingly, the remaining 10-20% is recognized as a reserve portion for free use by local government. Local government can decide on this portion freely and conduct their own unique programmes to create incentives for local government to get revenue from local tax. Often, such an original programme can becomes an advanced programme or touchstone. The MIC can recognise potential policy needs through this programme, and sometimes the ministry picks it up as a national policy (Interview to the MIC).

The basic financial needs for the standardised local government are estimated as follows;

$$\text{Basic financial needs} = \text{Unit cost (regulated)} \times \text{Measurement} \times \text{Parameter} \qquad (4.1)$$

where,

Unit cost: how much programme cost is necessary according to the unit Measurement (per population, per km or per km^2)

Measurement: The basis of size to calculate the budget, and considering how much stock of anything local government has.

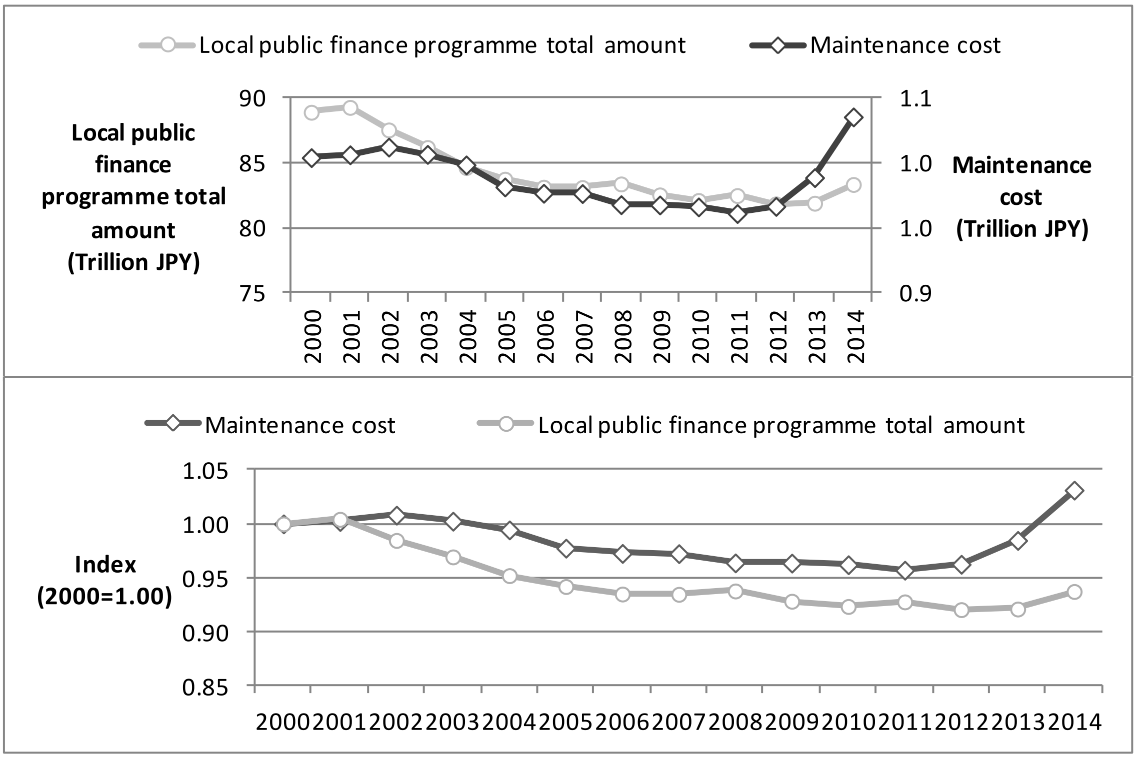
Parameter: type adjustment, class adjustment, density adjustment, aspect adjustment, cold region adjustment, rapid increase/decrease adjustment, financial strength adjustment and merging adjustments are introduced. Details are introduced in the following Table 25.

If the basic financial needs are estimated appropriately for each cost item, the necessary budget amount of infrastructure maintenance will be secured, but there is some space for discussing whether the basic financial needs about infrastructure management in this formula appropriately reflect the actual needs of infrastructure management costs.

Firstly, the unit cost is calculated with reference to the allocated basic financial needs for the cost items and the measurement. As mentioned above, the basic financial requirements is calculated based on the price indexes change and the amount of the infrastructure changes as well as the amounts of the last year’s local public finance programmes as a basis, while the original drafted amount is reviewed by the Ministry of Finance, and the reviewed amount is cut by 25% of local tax revenue. Accordingly, the unit cost does not in fact indicate the unit price of infrastructure maintenance per unit of infrastructure.

In order to utilise the unit costs in the formula as an actual indicator for monitoring the security of infrastructure development and management from the perspective of whether the budget has been secured, the unit cost should be adjusted by special fund portions, reserved (cut-off) portions, efficiency portion (the portion which change of price index and amount of infrastructure are not fully reflected by reviews of the Ministry of Finance). This adjusted unit cost can be considered as a monitoring measurement. Furthermore, the data for which parameters multiply the adjusted unit cost can be considered as the adjusted unit price for each element of local government (Interview to the MIC).

At this moment, the deterioration of the infrastructure is not considered in parameters. In addition, a demolition cost, which has not been needed so far, is not being clearly taken into consideration. On the other hand, the price index change and increments in the stock amount of infrastructure can be considered when the local public finance programme is developed, and local government can utilise the reserve portion for their own project ideas like demolishing deteriorated facilities while the MIC will reflect such unusual activity two years later. Therefore, in conclusion, this is not perfect, but the PDCA cycle on infrastructure management is practically running. In fact, the budget for maintenance cost in the local public finance programme for 2014 is more than that for 2013 (interview to MIC).



Source: Ministry of Internal Affairs and Telecommunication (each year)

Figure 65 Trend of maintenance cost and local public finance programme total amount

The financial parameter can, however, be criticised as the cause of 'wasteful public works'. This is because the finance parameter considering the amount of issued bond for infrastructure development allows the local government to issue the local bond more easily, so that it is pointed out that this parameter system has allowed local government to lose its fiscal discipline with regard to infrastructure development (Nikkei business, 2001).

The above mentioned criticism is one of the negative aspects of grant-in-aid from local allocation tax, showing that the unit costs and parameters should be monitored as to whether they are appropriate, but roughly speaking, the current grant-in-aid from the local allocation tax system can more or less provide a stable financial source for infrastructure development and management in local governments.

Table 23 Unit costs for roads in standard prefectures

Item	Measurement	Details	Breakdowns	Definition	Unit cost	Unit
Road	Area of road	Road general affairs	Salaries	70 officers	448,650	Thousand JPY/㎢
			Demand cost	Maintenance and repair costs of traffic safety facilities (Public safety commission)	268,800	Thousand JPY/㎢
				Maintenance and repair costs of traffic safety facilities (Road manager)	192,000	Thousand JPY/㎢
				Cost of streets and tunnels	227,670	Thousand JPY/㎢
				Others (Service, equipments and travel costs)	29,893	Thousand JPY/㎢
		Road maintenance	Contractors costs	Road maintenance, repair, material equipment and demand costs	3,138,104	Thousand JPY/㎢
				Bridge maintenance and repair special programme cost	417,000	Thousand JPY/㎢
				Increments of road maintenance and repair cost	157,700	Thousand JPY/㎢
			Outsourcing cost	Road surface cleaning and street trees thinning cost	125,480	Thousand JPY/㎢
	Length of road	Road improvement	Development cost	Direct management project (National expressway development including an equivalent amount for local bond interest, principal redemption amounts and subsidised programme costs	4,927,000	Thousand JPY/㎞
				Independent project costs	2,355,000	Thousand JPY/㎞
				Equivalent amounts of local bond interest and principal redemption amounts	2,622,000	Thousand JPY/㎞
		Traffic safety facility development	Development cost	Road manager portions (Direct and subsidized project)	399,000	Thousand JPY/㎞
				Road manager portions (Independent project)	963,000	Thousand JPY/㎞
				Public safety commission portions (Subsidized projects)	707,000	Thousand JPY/㎞
				Port authority (Independent projects)	446,000	Thousand JPY/㎞

Source: Chiho Kohuzei Seido Kenkyukai ed. (2013a)

Table 24 Unit costs for roads in a standard municipality

Item	Measurement	Details	Breakdowns	Definition	Unit cost	Unit
Road	Area of road	Road general affairs	Salaries	7 officers	37,880	Thousand JPY/㎢
			Demand cost	Traffic safety facility maintenance and repair costs (Public safety commission portion)	5,060	Thousand JPY/㎢
				Street and tunnel costs	11,760	Thousand JPY/㎢
				Others (Service, equipments and travel costs)	125,825	Thousand JPY/㎢
				Bridge maintenance and special repair programme cost	13,800	Thousand JPY/㎢
			Outsourcing	Road surface cleaning and street trees thinning cost	19,210	Thousand JPY/㎢
	Length of road	General road improvement	Development cost	Direct management project (National expressway development including equivalent amounts to local bond interest and principal redemption amounts and subsidised programme costs	114,000	Thousand JPY/㎞
				Independent project costs	76,000	Thousand JPY/㎞
				Equivalent amount to local bond interest and principal redemption amounts	7,800	Thousand JPY/㎞
		Traffic safety facility development	Development cost	Road manager portions (Direct and subsidized project)	100	Thousand JPY/㎞
				Road manager portions (Independent project)	11,500	Thousand JPY/㎞

Source: Chiho Kohuzei Seido Kenkyukai ed. (2013a)

Table 25 Parameters to adjust the gap between the standard municipality and actual municipalities

Parameters	Definition
Type	Differences of the unit costs with regard to the types of measurement
Class	Size effects: Increase or decrease in the administration costs depending on the magnitude of the value of the unit of measurement
Density	Increase or decrease up to population density. The difference between the densities of the specific unit cost to compare with standardised local government density
Aspect	Urbanization, isolation, agricultural/forestry area, administration authority, age structure of teachers, the necessity of investment, the necessity of reimbursement of local debt and so on.
Cold region	Adjustment of the increase owing to the cold and snow
Rapid growing	Adjustment cost increase owing to rapid population increase
Rapid declining	Adjustment cost decrease owing to rapid population decline
Financial strength	The ratio of the equivalent amount to local bond interest and principal redemption amounts set against the tax revenue
Merger	A part of the equivalent amount of local bond interest and the principal redemption amount for the promotion of town development in merged municipalities and a certain ratio for the standard whole project costs resulting from merged municipalities

Source: Chiho Kohuzei Seido Kenkyukai ed. (2013b)

Table 26 Application of parameters to adjust the gap between the standard municipality and actual municipalities in prefectures

Cost	Measurement	Type	Class	Density	Aspect				Cold region			Rapid increase		Rapid decline	Legal
					General	Ordinary	Investment	Finance	Difference of salaries	Cold	Amount of snow	I	II		
Road and bridge development cost	Area of road			○	○					○	○			○	
	Length of road						○	○		○	○				
Flood control cost	Length of river														
Port cost	Length of mooring facility in ports	○													
	Length of mooring facility in fishery ports														
	Length of protective facilities in ports							○							
	Length of protective facilities in fishery ports						○	○							
Other civil engineering cost	Population		○	○											

Source: Chiho Kohuzei Seido Kenkyukai ed. (2013b)

Table 27 Contents of adjustment in prefecture

Cost	Adjustment	Contents
Road and bridge cost	Density	Increase in accordance with traffic volume
	General aspect	Special case ・Because the burden ratio on the national highway in Hokkaido and Okinawa is different ・Designated city inclusive prefecture
	Investment	Calculation of the necessity of road development using several indices (undeveloped road length ratio and traffic volume etc.)
	Finance	Extra road development bond, local road development project costs, general independent project costs, general public works for project bonds, local bond interest and principal redemption amounts
Flood control cost	Finance	①local bond interest and principal redemption amounts on flood control and sand protection projects ②Extra flood control facility development project bonds and its interests and principal redemption ③Flood control and other related public works promotion projects bond interests and principal redemption ④local bonds′ interests and principal redemption for waste water management specified flood control facility development, houses and housing land foundation specified flood control facility development and urban park related specified flood control facilities′ development
Port cost	Type	Differences of the costs from the types of ports (International strategy port, international hub port, major ports, regional port)
	Investment	Fishery ports (adjustment using the ration of the number of fishery business and the fishermen)
	Finance	①Port portion (local bonds′ interests and principals redemption on port development) ②Fishery port portion (local bonds′ interests and principals redemption on fishery port development)
Other civil engineering cost	Density I	Population density
	Density II	①Adjustment of the cost equivalent to the subsidy for the compensation of tenant fee using land clearance and formation cost for public housing ②Adjustment of the cost equivalent to the subsidy for the compensation of tenant fees using neighbourhood housing tenant fee methods

Source: Chiho Kohuzei Seido Kenkyukai ed. (2013b)

4.3.5.2 Comprehensive subsidies for infrastructure development (MLIT)

In Japan, MLIT provides financial aid to local government for the development and management of road, waste water management, urban park, airport, port, coastal protection, public housing, flood control. Concretely, it provides comprehensive grants for infrastructure development (Syakai Shihon Seibi Koufukin) for new developments and grants for anti-disaster and safety (Bousai Anzen Koufukin) for maintenance, replacement due to deterioration as well as recovery from the damage by disaster.

The processes of application for these two grants are the same. Firstly, local government consults regional MLIT's office, and regional MLIT office summarises the requests from local governments in the region and propose the budget draft to the central MLIT. Second, MLIT also summarises all demands for the grants and then negotiates with Ministry of Finance (MoF). MoF reviews the necessity of grants budget draft, and cut down in some extent. In this process, central government ministries do not discuss project ideas but just discusses the upper limit of the budget. Therefore, the gap between initial drafts based on the project idea and the budget is expected to be managed well by local government. Some local governments reduce the amount of public works, and the others may change the method of public works. This is to the responsibility of local government (Interview with MLIT).

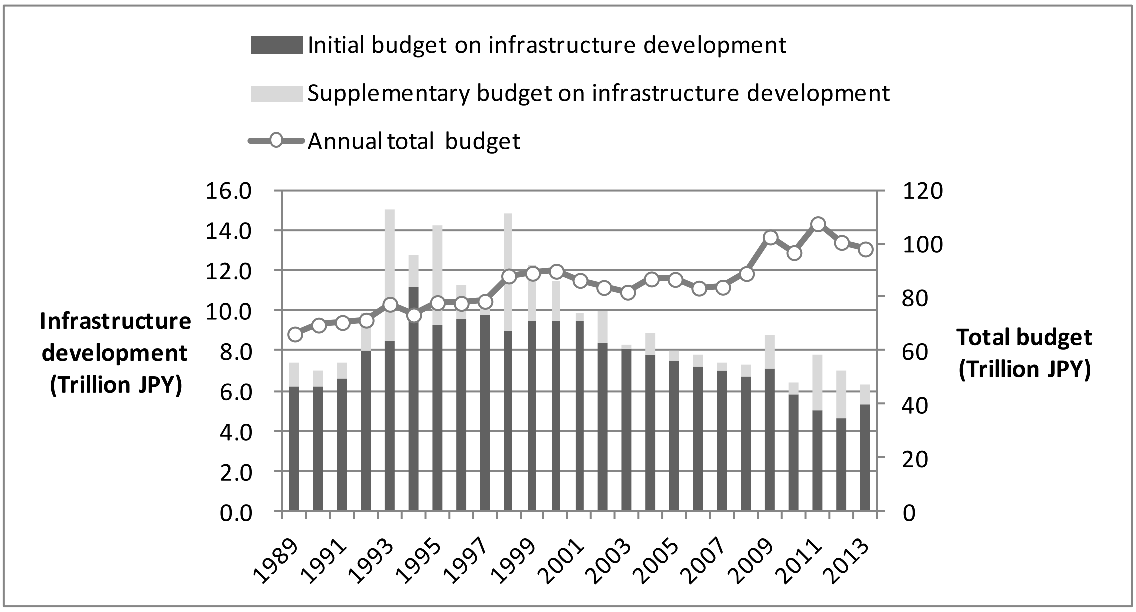
The central government and local governments are equal partners in the Japanese policy system, so that the MLIT cannot order the promotion of projects, but can only publish the outline of how to utilise the grants. The MLIT has introduced the standardised maintenance criteria of four stages all over Japan in terms of service level. In addition, the inspection methodology has also changed to the next to the infrastructure. MLIT can, however, only recommend them to local governments but cannot control them directly. Whether new developments are prioritised or maintenance works are prioritised are decided by local government. The balance between new development and maintenance works must be decided by local politician, residents and local government officers and the officers in MLIT. Therefore, disclosure of information and support for decision making will become more important (Interview to MLIT).

In this way, MLIT has already prepared a special fund for infrastructure development and management separately from MIC. At this moment, there is no way to assess the validity of the amount against the technical demands of financial sources but it can be said that they are secure financial source for infrastructure development and management to some extent.

4.3.5.3 Ministry of Finance (MoF)

MoF always reviews the budget requests from other ministries as mentioned before on the local public finance programme in MIC and comprehensive grants for infrastructure development or grants for anti-disaster and safety in MLIT.

The trends of national budgets for these 25 years are constantly increasing with slight fluctuations. On the other hand, the budget for infrastructure development excluding the grant-in-aid from local allocation tax peaked out in 1998 and declined after that year (Figure 66). This is because the cost reduction programme on public works has been introduced since 1998 and between 2008 and 2012 still continued to reduce 15% of total costs comparing to the total costs in 2007 (Relevant ministries and agencies liaison conference on administrative efficiency in May, 2008).



Source: Ministry of Finance (2013) Financial statistics, Table 19, http://www.mof.go.jp/budget/reference/statistics/data.htm

Figure 66 Total budget and initial and supplementary budget on infrastructure development

Simultaneously, the MoF has not conducted simple cut-offs of the budget on infrastructure development and management by following the yearly change of the policy by the MoF. The MoF is reducing but emphasizing the budget for infrastructure development and management (Table 28). For example, the following policy is announced in the direction for the 2014 budget session:

"It is necessary to promote well-planned infrastructure development and management to exert the existing facilities' function considering future people's living under severe budget constraints in terms of infrastructure development and management hereafter (Cabinet decision on 12th December, 2013)" and pointed out the following:

It is necessary to make the new infrastructure development and management more efficient by emphasising from the perspective of strengthening international competitiveness and anti-disaster countermeasures, by selecting projects and by using new technologies based on the previous improvement of development level of infrastructure and future population decline under the severe financial constraints.

It is necessary to secure the budget for sustaining the function and safety of necessary infrastructure against increasing the maintenance and replacement costs of existing infrastructures.

It is necessary to cope with the reduction needs of infrastructure stock amounts and service level down to secure the financial source for the above mentioned correspondence efficiently and based on the plan. For such a purpose, it is necessary to present the outlook of future maintenance costs and urgent replacement investments.

In particular, it is important for local governments to respond to such social needs, provided that most of the infrastructure is managed by local governments. The local governments should develop plans for extending infrastructure life-span or comprehensive management plans of public facilities including a selection of infrastructures based on their financial bearing capacities and regional demographic change.

The lack of engineers and members of the workforce in construction sites has also been pointed out recently. Providing that the working age population declines, it is difficult to increase the investment for construction even considering private investments, so that the number of engineers and workforce in construction sites will highly probably and naturally decline in the future. Therefore, it is necessary to conduct investments in order to develop the countermeasures of creating more efficient construction technology and technical innovation to cope with the increase in future maintenance and replacement works under severe financial constraints (Ministry of Finance, 2014).

In this way, it can be found that MoF shares a common sense of crisis with MLIT and other related stakeholders, and the consciousness of this sense of crisis seems to be reflected in the reviews of budget drafts made by the other ministries.

Table 28 Policies on budget allocation

Period (Fiscal year)	Policy for the budget
1989-1990	The budget size was secured to a rate equivalent to that of last year, considering a sustainable expansion of the domestic market but not to stimulate the domestic economy too much because the economy steadily declined.
1991－1997	The initial budget was suppressed and the supplementary budget increased too much because of the stimulation of the economy, considering the advent of a fully-fledged ageing society, economic trends, the necessity to promote infrastructure development, a severe public finance situation, and a basic public investment plan as well as emphasising the sector being directly linked to improve the national quality of people’s lives.
1998	The budget was reduced by 7.8% less than that of last year and was the suppressed because of the depressed economic situation, the necessity of policy reform for infrastructure development and public finance as well as being based on the special measure law on public finance structural reform, and by emphasising the sector’s contribution to the improvement of the efficiency of logistics.
1999-2001	The budget was increased by 5.0% more than in the last year by emphasizing the sector’s contribution to the improvement of the efficiency of logistics, in order to contribute to the economic recovery and the promotion of infrastructure development before the advent of a fully-fledged ageing society.
2002	The budget for public works was cut by 10% compared to the initial budget in 2001, and then conducted emphasized allocation to the seven sector (the environment, low fertility rate and ageing, revitalization local community, urban regeneration, science and technology, human resource development and IT) introduced by the “Basic policy on structural reform of economic and social economic and fiscal management in the future (Cabinet decision, 6th June 2001)

2003－2005	The budget for public works was cut by 3% compared to the equivalent amount in the initial budget amount over the last year, and then allocated intensively to four areas “human power enhancement, education, culture and science and technology”, “attractive urban and rural areas with ingenuity and individuality”, “Safe and fair aged and low fertility society” and “Recycling society and global warming issues” which link to issues of sustainable future development.
2006-2009	The budget for public works was still cut off by constantly by 3% and allocated intensively to revitalizing region, strengthening growth power, securing the safety and security of people with corresponding urgent issues. Also abolishing the special road funding policy and creating a new policy of grants for the creation of regional vitality foundation and furthermore, 60 billion JPY being transferred to the financial source of social security.
2010	The government changed to the Democratic party, and launched the concept of ”from concrete to human being”. This led to the reduction of the public works budget by 5.7 trillion JPY between 2010 and 2013. Also, an individual subsidy for infrastructure development, along with a comprehensive grant system for regional infrastructure development and agricultural or fishery village development was created.
2011	The budget for public works was reduced by 5.1% against the budget in last year, and then allocated intensively to safety and security areas because of the ‘New growth strategy’ (Cabinet decision, 18th June, 2010)
2012	The budget for public works was reduced by 3.2% from last year but a special fund of 722.8 billion JPY was prepared for recovering damage from the East Japan Earthquake.

Source: Ichikawa (2013), pp.145-147

4.4. SUMMARY

This chapter has introduced the history of infrastructure development in Japan, the differences in the accumulation of infrastructure stock, and also a financial system for infrastructure development and management.

As for reviewing the flow of investments for infrastructure development and management as well as stock accumulation, the peak excluding public housing was reached in the 1990s. This means that most of the Japanese infrastructure is still new, and the problem caused by year-passed deterioration of them has not yet occurred.

Local governments have been supported by a grant-in-aid system for two years ago which takes into consideration financial closure, price index changes and a change in the infrastructure amount.

It has been found that that the financial system can secure financial resources in some extent despite critics losing fiscal discipline on local bond issues, while the grants from MLIT have not necessarily been stable. Accordingly, infrastructure development and management costs have somehow been secured through a local government support financing system in Japan.

In the future, the difficulties of maintenance and replacement of infrastructure has been often pointed out, but this risk has been already recognized by the MLIT, MIC and MoF. Those ministries recommend that local government take precautionary countermeasures. Of course, not all local governments can cope with the recommendations of the central government, but it is expected that local government will gradually be able cope with the potential risk of infrastructure development and management of a society that is being depopulating. The problem will be how to cope with this.

In the later chapters, in order to examine how to manage such issues, discussions will be conducted about the actual situation, as well as about issues and problems related to infrastructure management in depopulating municipalities. Also, the issue of recognition by the end-users of issues related to infrastructures will be considered and reviewed carefully.

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CHAPTER 5: SUSTAINABILITY

5.1 INTRODUCTION

As presented in the introduction chapter, here, the concept of sustainability is discussed to clarify what is "infrastructure sustainability" before starting the main discussion.

First, the history, the typical definition of sustainability, and related concepts on sustainability are introduced. Second, the definition of infrastructure sustainability given in previous studies is introduced and also the definition of the outline and arguable points of the concept of sustainable development in this study are presented. This is only the outline and through the discussion in the following chapters, the rough concept will be examined and interpreted in particular in the discussion and analysis chapter based on the study results. The previous research results are introduced in the results section, and the rest is discussed in the discussion section. Third, the reason why the sustainability concept is introduced in this study more clearly based on the nature of infrastructure in order to stress its merit for this study is discussed. This is also shown in the discussion section.

5.2 METHODOLOGY

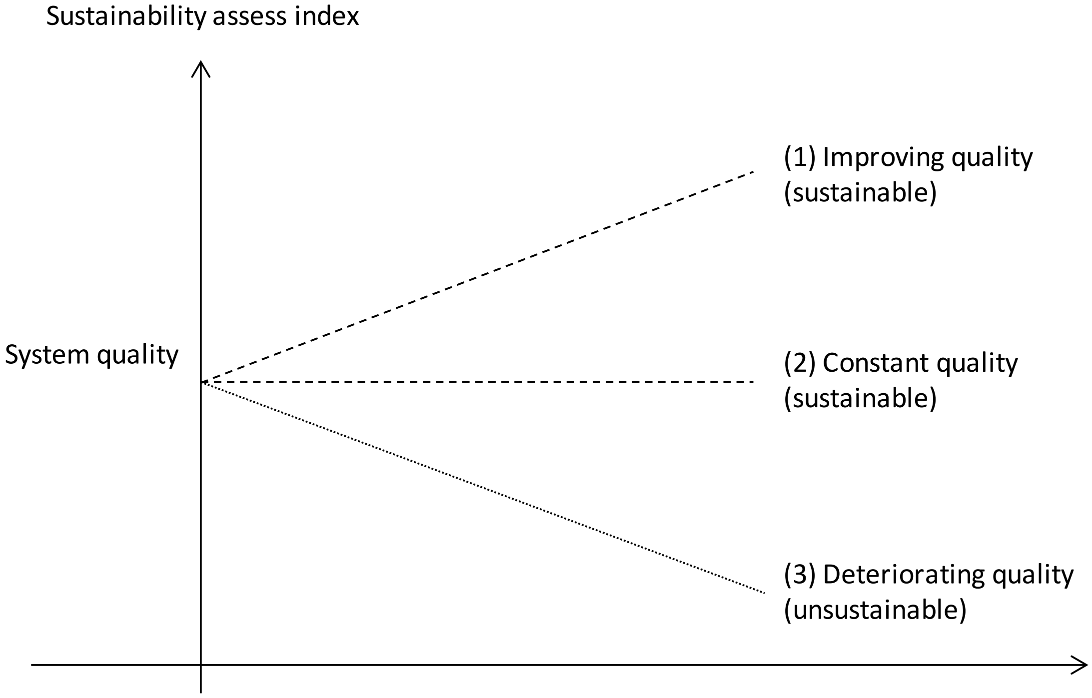
A literature survey is used for this chapter. In terms of "sustainability", there are some books as well as academic journal papers. For the general "sustainability" discussion, books that included the words "sustainability" or "sustainable development" in the titles were collected. With regard to "infrastructure sustainability", the books often discussed the design matter or typically focused on energy and resource consumption and the journal articles that included the words "sustainable" or "sustainability" in their title was selected.

5.3 RESULTS

5.3.1 GENERAL SUSTAINABLE DEVELOPMENT AND SUSTAINABILITY

Many frameworks for discussing sustainable development are proposed, although there is no entrenched definition of "sustainable development" (e.g. Bell and Morse, 1999; Parkin, 2000; Jeon and Amekudzi, 2005). These discussions, on the other hand, also mention that the definition of sustainable development is often regarded as being linked to the following: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987)" (Bell and Morse 1999). In fact, some previous research has employed the WCED's definition as its definition of sustainable development (Hediger, 2000; Little, 2005).

In terms of the concept of sustainability, the objectives of the discussion on sustainability are explained as follows: "increase in system quality" or "sustaining system quality" are regarded as "sustainable"; and, in the same way, "decline in system quality" can be defined as "unsustainable" (Bell and Morse, 1999). Figure 67 illustrates the idea of this definition.



Source: Bell and Morse (1999). Sustainability and sustainability indicators. In: Sustainable Indicators: Measuring the Immeasurable. Earthscan: London, p. 9.

Figure 67 The definition of sustainability from the perspective of system quality

Figure 67 is an instinctively understandable explanation of sustainability; however, many counterarguments have been presented against this chart for explaining the definition of sustainability. The representative points are as follows: first, what system quality means; second, how the special range is defined in order to define quality; third, how the time axis is defined in order to evaluate quality appropriately; and fourth, how the difference between weak and strong sustainability is considered in this context (Bell and Morse, 1999). It is possible to regard these counterarguments as the viewpoints that should be employed when we consider what infrastructure sustainability is.

In addition to the above-mentioned points, previous sustainability discussions were addressed from the viewpoint of how society should be developed in accordance with population growth, while very few studies mentioned sustainability in the context of population decline (Asheim et al., 2007). Furthermore, neoclassical economics usually defines sustaining per capita consumption (Hartwick's rule) as sustainability, or sometimes assumes that the population growth rate should be zero; in other words, population should be stable. Consequently, these assumptions could, sometimes, result in researchers and economists being deprived of the opportunity of considering how demographic change will affect the Japanese society. To prevent such a situation, it could be seen as significant that we would discuss infrastructure sustainability in the context of demographic change from those five perspectives, society, economy, environment, engineering and inter-temporal change of system quality, previously mentioned.

There are several definitions of the measurement objectives of sustainability: for example, "per capita utility should be sustained" (Hediger, 2000; Neumayer, 2003), "per capita consumption should be sustained in the context of weak sustainability" (Faucheux et al., 1997) and "saving should be more than depletion" (Pearce and Atkinson, 1993).

The first definition, that "per capita utility should be sustained", is applied to the definition of infrastructure sustainability, but possibly contradicts the idea that infrastructures do not produce any utility, as discussed in Neumayer (2003). Of course, future discussion may resolve this contradiction, but it is probably true that most infrastructures do not produce direct utility compared with using them in the process of economic production.

The second definition, that "per capita consumption should be sustained", can be considered as a candidate for the definition of infrastructure sustainability. This is because the usage of infrastructures is the consumption of infrastructures, and the per capita opportunity to use infrastructures will possibly be sustained in the future. Note that this consumption is, however, not necessarily equal to the consumption of final goods in economic terms.

In the third definition, that “saving should be more than depletion”, infrastructure sustainability is defined as follows: the gross stock of infrastructure should be more than the depletion of infrastructures owing to time passing and usage. This definition appears to be natural, but another point also has to be discussed: that is, which aggregated net stock of infrastructures in society, or per capita stock of infrastructures, is appropriate. Generally speaking, the description of something as being “per capita” is often applied for the discussion of sustainability in economics. Hence, the idea of anything being “per capita” should be accepted in the succeeding discussion.

On the other hand, the concept of sustainability is sometimes defined as a concept containing “quality of life” (Bell and Morse, 1999). If not, the sustainable condition is defined as “capacity for continuance” (Parkin, 2000). To consider such conceptual definitions as “quality of life” or “capacity for continuance” more fully the idea of “sustainability” is often discussed from three perspectives: society, the environment and the economy (Elkington, 1997). The idea, in particular, of dividing the measurement objectives of sustainability into several aspects is common in the discussion of infrastructure sustainability (Dasgupta and Tam, 2005).

“Weak sustainability” and “strong sustainability” are also popular concepts of sustainability. “Weak sustainability” is considered as “environmental quality [that] can be traded against economic gain; to help make all of this easier, the environment is ‘valued’ in monetary terms” (Bell and Morse, 2008; p. 14). On the other hand, “strong sustainability” is considered as “no trade off between economic gain and environmental quality [which] is acceptable” (Bell and Morse, 2008; p. 14). Infrastructure is man-made capital and is not environmental resources and quality. Accordingly, the sustainability of infrastructure can be considered a type of weak sustainability.

This nature of weak sustainability of infrastructure is clearly described: “adequate financing must therefore be considered an essential factor in improving the sustainability of infrastructure systems, where sustainability refers to the ability of a system to function long into the future” (Martland, 2012; p. 5) and “poorly managed infrastructure systems that steadily deteriorate, become congested, or become unsafe clearly are not sustainable” (Martland, 2012; p. 5).

The concept of sustainable development very often applies to discussions of society both in developing and developed countries, but the implicit assumption tends to be a stable population. For example, in the seminal paper where the overlapping generations model was developed, Samuelson (1958) used the strong assumption that "the simplest case to answer this question is that of a stationary population, which has always been stationary in numbers and will always be stationary. This ideal case sidesteps the difficult 'planning-until-infinity' aspect of the problem (Samuelson, 1958; p. 469). Samuelson also discussed intertemporal decision making under population decline (Samuelson, 1958), but it was in a different context from the sustainability discussion. This point will be discussed again in chapter nine, in which intertemporal decision-making issues by citizens is discussed based on Samuelson's and Barro's previous research results (Barro, 1974; Barro 1979; Samuelson, 1958).

5.3.2 SUSTAINABLE DEVELOPMENT OR SUSTAINABILITY OF INFRASTRUCTURE

In response to recent abnormal weather and countermeasures for global warming, several studies of sustainable infrastructure development have been published (Sarte, 2010; Pearce, Ahn, and HanmiGlobal, 2012; Martland, 2012). These have mainly been discussions about saving energy resources and how to finance infrastructure development and management. In particular, existing discussion of the sustainability of infrastructure is in regard to buildings. The term "green building" has recently become very popular in the context of sustainable development as "in the construction industry, sustainable design and construction (also referred to as green building, high-performance building or environmental friendly building) is considered as a way for the construction industry to move toward achieving the objectives of sustainability" (Pearce, Ahn, and HanmiGlobal, 2012; p. 7). They, however, have not pointed out the existence of a balance between multiple aspects and intergenerational equity regarding sustainable development and management of infrastructure in the context of population decline.

The discussion dividing the contents of "infrastructure sustainability" into three aspects (society, the environment and the economy) can be seen in several previous studies, as well as that for general sustainability (Azapagic, 2004; Jeon and Amekudzi, 2005). For instance, the Centre for Sustainable Transportation (CST) in Canada has defined infrastructure sustainability in the following words: "Sustainable transport allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations [social aspect]; is affordable, operates efficiently, offers choices of transport mode, and supports a vibrant economy [economic aspect]; and limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, reuses and recycles its components, and minimizes the use of land and the production of noise [environmental aspect]" (CST, 2003).

There is also discussion considering aspects other than those three. For example, the addition of an engineering aspect (Sahely et al., 2005) or of resource utilization, health and safety, and project management/administration (Ugwu and Haupt, 2007) represents this type of discussion. In particular, in terms of the aspect of engineering, it is noted that it is important to consider reliability, resilience vulnerability, risk, reversibility, robustness, synergy, simplicity, functionality, adaptability, diversity, durability and carrying capacity as the elements of infrastructure sustainability (Sahely et al., 2005).

Compared with other previous research, Martland discussed three aspects of infrastructure. He presented the assessment framework of social, environment and economic impacts on infrastructure (Martland, 2012). He introduced the social impact assessment framework by the Interorganisational Committee on Principles and Guidelines for Social Impact Assessment (ICPGSIA). The framework includes population change and community structure, etc., but gives only categories and does not discuss the actual impact of population decline on infrastructure.

Apart from the impacts of demographic change, it has been revealed that the deterioration of infrastructures from the engineering perspective caused serious social problems in the U.S. (Choate and Walter, 1983). These engineering aspects can also be considered as safety issues being separated abstractly from the social aspect. Accordingly, if the social aspect contains the matter of engineering safety, it is certain that there is no need to separate it; however, the need to pay special attention to the condition-based management of infrastructures to prevent any social problems from happening is insisted on in the context of asset management of infrastructures in the civil engineering field (Kobayashi, 2000). Hence, the separation of the engineering perspective from the social aspect can be considered important in order to discuss it clearly.

5.4 DISCUSSION

5.4.1 DEFINITION OF INFRASTRUCTURE SUSTAINABILITY IN THIS STUDY

As mentioned above, the idea that the discussion of infrastructure sustainability is based on per capita indicators in terms of four aspects, i.e. society, engineering, the environment, and the economy, can be considered rational. The possible subcategories and contents for these four aspects are shown in Table 29. For example, sustaining the per capita opportunity to use infrastructures and sustaining per capita net saving are very much categorized as social aspects. The engineering aspect may include not only the safety (in other words, technical condition) of infrastructures, but also the number of engineers necessary to conduct maintenance work. Environmental aspects can be divided into three subcategories, such as resource usage, pollution and landscape. The average per capita user financial burden is, of course, assumed to be contained in the economic aspect. Note that these subcategories and contents are conceptual examples at the moment, which remain to be discussed in the ensuing literature review, in conducting interviews, in the relative empirical surveys, and so on.

Table 29 Four aspects of infrastructure sustainability and their subcategories and contents

Aspect	Subcategory	Examples of assumed contents
Society	Accessibility	Infrastructure stock per capita Time and distance to the infrastructure
Engineering	Safety	Technical condition of infrastructure The number of engineers
Environment	Resource usage	Resource consumption in infrastructure development and replacement (concrete, iron, timber, etc.) Utilities (electricity, water, etc.) for infrastructure management
	Pollution	Air pollution, noise, odour, etc. in infrastructure usage
	Landscape	Consciousness of the landscape change owing to infrastructure development and post-closure management
Economy	User charge, tax, etc.	Average user financial burden per capita

This study uses the categories and contents of infrastructure sustainability as the definition of the four aspects of the sustainability of infrastructure development and management. In addition, the condition of sustainable infrastructure can be considered as the service level of infrastructure in the future should still be kept much more than now on a per capita basis.

In order to analyse the impact of population decline on infrastructure systems, the concept of the sustainability of an infrastructure system was considered. The concept of sustainability is well known but varies according to context. The 'triple bottom line' – society, the economy and the environment – constitutes the conventional idea of sustainability. Some researchers use this definition for infrastructure systems (Sahely et al., 2005).

In the context of infrastructure systems, engineering is often considered as another crucial aspect (Sahely et al., 2005) in terms of the number of engineers, asset conditions, and so on. This is because the infrastructure system is a sub-system of society, and the social aspect of the aforementioned 'triple bottom line' is too broad a concept for discussion in its own right. For this reason engineering, as a social aspect of sustainability, is treated as an entity in itself in the present research. Therefore, the present study considered four aspects – society, engineering, the environment and the economy – as the framework for discussing the impact of population decline on infrastructure. The social aspects include social safety and accessibility, such as time and/or distance to the particular form of infrastructure. The engineering aspect includes the maintenance level and the number of in-house engineers. Landscape, pollution and resource use were considered as the main environmental aspects. Finally, per capita financial burden, such as user charges and taxes, and the impact on the economy of the municipality, were considered from the perspective of economic effects.

5.4.2 Significance of Introducing the Sustainability Concept

The "sustainability" concept usually applies to global warming issues and genetic resources (biodiversity), etc. Also, the concept applies to urban development, as well as recently to infrastructure development as introduced in the above section.

Environmental economists might perceive population decline as favourable in terms of sustainable development from an environmental and natural resource perspective. It is true that it may be so when only the environmental aspect is taken into consideration: declining populations will reduce the consumption of resources and the emission of pollution from human activities will also decline. In some cases, the land where human activities have been withdrawn from may be able to restore its natural vegetation and animal inhabitants after a certain period of time has passed. Nevertheless, it is also true that our lives depend on a very wide range of man-made things such as infrastructure and public good services.

Of course, the people living in the depopulating areas have the right to the pursuit of happiness. It is a fundamental human right in the Constitution of Japan. The government of Japan has to provide the minimum infrastructure service for depopulating areas as well. Accordingly, if some issues affecting the sustainable infrastructure service provision will happen, the government (in some cases, the private infrastructure manager) has to cope with it anyway even if it is demolished because infrastructure is fundamental to human life in the region.

In contrast to natural goods such as forests, which are also public goods from a global warming perspective and have the potential capacity to naturally regenerate in hundreds of years, man-made public goods need to be taken care of because they naturally decay and depreciate with time and only artificial activities like replacement or rehabilitation can sustain them for a certain period (Martland, 2012). Without such maintenance, derelict infrastructure may in fact negatively impact the environment through, for example, landscape deterioration and visual disamenity.

The nature of infrastructure resembles exhaustible resources like fossil fuel, while it also has a similar nature to renewable resources like the forest because the infrastructure can be artificially reproduced by certain maintenance work. This hybrid nature of infrastructure should be taken into consideration when sustainable infrastructure development and management and the path to sustainable infrastructure development and management from the current situation are discussed.

Furthermore, when discussing the sustainability of infrastructure in Japan in the context of aging physical infrastructure and strong budgetary constraints, the discussion is assumed to sustain all infrastructures that are working (Ushijima, 2013). This discussion assumes to keep the level of infrastructure service provision implicitly, in particular, from the infrastructure manager perspective. This discussion is a little similar to conserving biodiversity or genetic resources. This similarity is to sustain the existence of the resources. Of course, the genetic resources of extinguishable goods and infrastructure of artificial renewable goods are completely different. Therefore, this difference should be involved in the following discussion. “Weak sustainability concept” as introduced above is very useful to reflect this difference of the nature of the goods because the “weak sustainability concept” allows the discussant to assume the reduction of infrastructure service provision on the condition that the total level of infrastructure service provision with reduction of the financial burden will persist.

In conclusion, it is not only because of the lack of previous research on the impact of demographic change – in particular, population decline – but also because of its necessity and the nature of infrastructure management that this study focuses on sustainable development and management of infrastructure in a depopulating society, and it can be considered that the discussion on the infrastructure sustainability is very significant.

5.5 Concluding Remarks

This chapter introduced the sustainability of infrastructure and applied the concept to infrastructure. Also, the significance of introducing the “sustainability concept” for this study is explained. The details of the sustainability of infrastructure development and management will be indentified in the following chapters to conduct field surveys.

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Chapter 6: Literature review: The impact of population decline on infrastructures: A literature review[2]

[2] A version of this chapter is forthcoming as Uemura, T. and Mourato, S. (forthcoming) The impact of population decline on infrastructures: A literature review, Review of Urban and Regional Development Studies, forthcoming.

6.1 INTRODUCTION

This chapter reviews previous research by examining the scope of past literature, the extent of demographic change, the causes of population decline, the type of infrastructure affected, the type of geographical features observed, the methodologies used, the impacts observed, and the countermeasures proposed. This review will be the starting point for this thesis.

These perspectives were introduced for the following reasons.

First, demographic change is a key aspect of this chapter because the discussion of infrastructure development is normally conducted either to cope with economic growth or to conquer the congestion caused by both population and economic growth. Population decline is a symmetrical phenomenon, but it is rarely considered in the discussion of infrastructure development thus far.

Second, in Japan, residential areas spread from city centres to rural areas in plains areas sequentially, and natural geographical constraints such as rivers and mountains often separate urban areas and settlements as seen in chapter 3. Furthermore, land is often used for a variety of purposes, e.g. for both commercial and industrial usage in one city, or for large factories located in agricultural areas. Accordingly, the differences in terrain such as slopes, plains or mountains and industrial location should be considered as more significant factors than the differences between urban areas and rural areas in the discussion of this topic.

Third, the concept of sustainability is applied in this chapter to discuss the impact of population decline. As introduced in chapter 5, it is true that there are many discussions on sustainability or sustainable development, but this chapter only applies the basic idea of sustainability, i.e. subcategories of sustainability and the intergenerational equity concept, in order to discuss infrastructure sustainability within the context of population decline. In terms of subcategories of sustainability, the four aspects of society, engineering, the environment and economy (Sahely et al., 2005) can be considered as the engineering perspective is very relevant and can allow us to discuss this topic in technical terms.

The types of infrastructures addressed in this chapter are various and the mostly developed, operated and maintained by the government in Japan. Roads, flood management, public housing, water supply and wastewater management, railways, airports, ports, life-support facilities, education, social care facilities and so on are assumed to fall within its remit. Electricity and gas are owned by private companies heavily regulated by the government in Japan. Accordingly, these sectors are also included in this research.

The chapter is organised as follows: section two describes the methodology. Section three discusses the extent of population decline, the causes of population decline, the types of infrastructure, analytical methods, reported impacts and countermeasures. Section four outlines the conclusions of this chapter and highlights future research topics.

6.2 Methodology

Mainly adopting the literature survey method, this chapter reviews the literature conducted in the following areas: regional science; engineering; geography; urban planning; rural planning; economics as well as shrinking cities. Engineering aspects, for example, are therefore discussed under engineering, and social aspects are discussed under social science. In the survey of the literature, the terms “population decline”, “infrastructure” and “impact” were used. “Depopulation”, ”demographic change” (rather than population decline), individual infrastructure type such as “water supply”, “wastewater management”, “roads” and “public facilities” (instead of infrastructures) and “impact problems” were also used. Google Scholar, LSE cross-search, Google, the British Library and the National Diet Library databases were used to search the literature.

In terms of literature related to “shrinking cities”, I visited the CIRES website (http://www.shrinkingcities.eu/index.php?id=83) and conducted a title search using the words: “infrastructure”, “facilities”, “transport”, “water”, “road” etc., but no related literature for this study was found. A slight number of studies and books could be found related to shrinking cities and were included in these research results. Furthermore, two or three times as much literature appeared on the website when searching for “shrinking cities” and “infrastructure” or related terminologies, but interestingly, very few descriptions of infrastructure in the context of population decline could be found. Sometimes, there were a few words. For example, 'excessive infrastructures and services create inefficiency and financial burdens for local governments. To cope with this issue downsizing and greening infrastructures are two commonly used strategies. One strategy used by authorities of many shrinking cities is to match infrastructure requirements with lower population level' (Richardson and Nam, 2014: p.187). Otherwise, there was no specific or in depth discussion on physical infrastructure issues for general use but cultural and social infrastructure (Pallagst, Wiechmann, and Martinez-Fernandez, 2014) with superficial or general statements. Thus, this chapter has only referred to the literature with in depth and detailed discussions with regard to infrastructure issues in shrinking cities like Koziol (2006), Rink et al. (2009) and Rink et al. (2010).

6.3 RESULTS

6.3.1 SCOPE OF THE RESEARCH

This section describes the extent of population decline, the causes of population decline, types of infrastructure and geographical variety. These factors could result from the variability of the impact of population decline on infrastructure development and management in similar depopulating areas.

6.3.1.1 Extent of population decline

Not all of the literature discussed the extent of the impact of population decline on infrastructure. The demographic change was basic information provided when the impacts of population decline on infrastructure were discussed, but very few researchers discussed the extent of population decline causing the impacts as most of the previous research was case studies meaning there was no comparison on the extent of population decline when the impacts were happening.

Of course, only the extent of demographic change was mentioned in the discussion of shrinking cities (Wiechmann and Wolff, 2013). Discussing the pattern of demographic change for 20 years, this study was followed by a series of case studies in COST ACTION that did not discuss the impacts of infrastructure sufficiently. For example, only one page was devoted to technical infrastructure and transportation (European Union, 2013).

In addition, the geographic scope of population decline causing the impacts was also an interesting topic, but according to various shrinking cities literature and other previous literature on the impacts of population decline on infrastructure suggested that the impacts may be happening in any geographical resolution of demographic change. In some literature, the depopulating areas in the city, the city-wide depopulation, and also nationwide depopulation were discussed. Therefore, the geographical scope was not as important because the impacts were pointed out in all geographical locations when the impacts of population decline on infrastructure are discussed, but clear descriptions or definitions of the geographical scope of demographic change should be noted to provide context for the discussion to guide the readers.

The reason why the extent of demographic change should be investigated is that it can be used as a proxy in order to anticipate when and where the impacts could potentially happen keeping in mind that other parameters of course will also impact depopulating areas. Actually, 'Taiwan's planning professionals have paid attention to how anticipated population decline may affect urban infrastructure' (Richardson and Nam, 2014:p.197). Therefore, the relation between the extent of population decline and the occurrence should be also examined in the following chapters.

6.3.1.2 Causes of population decline

Population decline can be caused by various factors, such as a natural decline owing to low fertility rate, social migration resulting from industrial decline, reunification etc.

The main causes of population decline cited in previous studies were a declining birth rate (Buhr, 2007; Just, 2004), industrial decline (Matsuno and Yoshida, 2008b; Ministry of Land, Infrastructure and Transport, 2007; Feser and Sweeney, 1999; McKenzie, 1999) and especially mine closure (Matsuno and Yoshida, 2008a; Uchida and Deguchi, 2006), ageing and social outmigration of young people (Furuyama, 2007; Taira, 2005; Roy and Matthew, 1995). In addition, the growth of neighbouring cities and changes in urban competency, such as a decline in the accessibility of public transport, was also noted (Ministry of Land, Infrastructure and Transport, 2007). Furthermore, natural disasters, serious pollution, increases in land and housing prices, reduced housing and obsolete or shrinking higher education colleges were also reported as minor causes of population decline (Ministry of Land, Infrastructure and Transport, 2007).

Almost all of the papers neglected the elements (causes, speed etc) of demographic change due to the lack of comparison studies.

6.3.1.3 Types of infrastructure

The kinds of infrastructure affected by population decline were many and varied.

Network infrastructures were typical cited as being impacted by population decline (Schiller and Siedentop, 2006). Roads (Matsuno and Yoshida, 2008a; Furuyama, 2007; Ministry of Land, Infrastructure and Transport, 2007; Ujihara et al., 2007; Feser and Sweeney, 1999) were typically discussed in Japan and the USA, but not in Germany. In addition, telecommunications (McKenzie, 1999) and agricultural irrigation systems (Furuyama, 2007; Ministry of Land, Infrastructure and Transport, 2007) were reported as well.

Water supply and wastewater management (point-network infrastructures) were easily affected by population decline (Buhr, 2007; Matsuno and Yoshida, 2008b; Furuyama, 2007; Ministry of Land, Infrastructure and Transport, 2007; Ujihara et al., 2007; Hummel and Lux, 2007; Moss, 2008; Feser and Sweeney, 1999; Hoornbeek and Schwarz, 2009). Utilities including electricity and gas supply, as well as water supply and wastewater management (Just, 2004; Ujihara et al., 2007), energy supply (Hummel and Lux, 2007; Hoornbeek and Schwarz, 2009), heat supply (Matsuno and Yoshida, 2008b; Hummel and Lux, 2007) and waste disposal systems (Just, 2004) were addressed in previous studies. Transport was also discussed in previous studies (Buhr, 2007; Taira, 2005; Roy and Matthew, 1995; Hummel and Lux, 2007; Just, 2004; Hoornbeek and Schwarz, 2009; McKenzie, 1999).

Typical point infrastructures affected by population decline included public housing, schools and healthcare facilities. In particular, severe impacts on public housing were reported in Japan and Germany (Buhr, 2007; Matsuno and Yoshida, 2008a, 2008b; Uchida and Deguchi, 2006; Furuyama, 2007; Ministry of Land, Infrastructure and Transport, 2007; Glock and Häussermann, 2004).

Similarly, schools (education) often showed severe effects of population decline (Matsuno and Yoshida, 2008a; Furuyama, 2007; Ministry of Land, Infrastructure and Transport, 2007; Taira, 2005; Roy and Matthew, 1995; Just, 2004; Feser and Sweeney, 1999; McKenzie, 1999). Healthcare facilities were also discussed (Buhr, 2007; Taira, 2005; Roy and Matthew, 1995; McKenzie, 1999). Other point-type infrastructures, including life-support infrastructures such as libraries (Furuyama, 2007; Ministry of Land, Infrastructure and Transport, 2007), conventional religious facilities such as shrines and temples, which traditionally provide meeting-places (Furuyama, 2007; Ministry of Land, Infrastructure and Transport, 2007), police stations and public administrative buildings (Roy and Matthew, 1995; Just, 2004), were also addressed.

All obvious infrastructures were reported on in previous studies, but anti-disaster facilities, airports and ports were not included. These types of infrastructure are important in Japan, comprising many islands vulnerable to natural disasters; therefore they should also be considered in future research.

6.3.1.4 Geographical variety

The geographical range described in previous studies can be divided into three groups: urban areas (Buhr, 2007; Taira, 2005; Hummel and Lux, 2007), rural areas (Roy and Matthew, 1995; Just, 2004; Feser and Sweeney, 1999; McKenzie, 1999) and those with no limitations (Schiller and Siedentop, 2006).

There was some research focusing on more specific areas, such as sprawling areas and well-planned developed areas (Ujihara et al., 2007). In terms of rural areas, mountainous areas in particular were discussed (Furuyama, 2007) and geographical features in the marginal areas between mountainous and plains areas comprised a more specific research interest (Ministry of Land, Infrastructure and Transport, 2007).

Elsewhere, region-specific industrial features were discussed by researchers interested in that region (Uchida and Deguchi, 2006). Furthermore, climatic features were also covered, and research was conducted on areas subject to heavy snowfall (Matsuno and Yoshida, 2008a).

Eastern Germany, Western Australia and the Midwest in the USA, unlike Japan, undergo only slight terrain changes, and so very few previous studies were focused on this issue. In future research, the effects of the Japanese terrain should be taken into consideration.

6.3.2 METHODOLOGY

6.3.2.1 Theoretical/research frameworks

The research frameworks used in previous studies can be divided into four main types: demographic change/population dynamics; the modern infrastructure ideal; the urban cycle hypothesis and sustainability.

The research on the demographic change perspective has discussed the relation between changes in population size, household size, population density, the demographic ageing process and the impact on infrastructures (Hummel and Lux, 2007). Furthermore, the relation between the regional boom and bust cycle with infrastructure was also analysed (Feser and Sweeney, 1999).

On the other hand, given that the modern infrastructure ideal comprises large-scale technologies, territorial monopolies of service provision, heavy public investment, strong state regulation, supply-oriented infrastructure planning and service provision by the state (or municipality), research examined the aspects most affected by population decline (Moss, 2008). Infrastructure managers faced with a diminishing demand for infrastructure owing to population decline have had to review and modify the initial infrastructure service provision plan developed by suppliers.

In addition to the individual infrastructure perspective, the urban cycle hypothesis has been applied to problems concerning infrastructure (Taira, 2005). For instance, the supply of infrastructure provision does not normally keep pace with demand during times of growth (as the population increases), whereas supply exceeds demand during a population decline. The greater the population decline, the greater the resulting excess of infrastructure. In contrast, a milder population decline allows infrastructure managers to mitigate the impact because there is ample time to cope with the situation. The process of population decline shifts continuously, but the capacity of infrastructure cannot be adjusted quickly, thus excess capacity is inevitable. Consequently, the additional operational and maintenance costs are unavoidable. In other words, a perfect shrinking equilibrium cannot be realised in the real world (Taira, 2005).

There were several studies applying the sustainability framework. For example, one defined rural sustainability as the ‘ability of rural communities to retain their demographic and socio-economic functions’ (Roy and Matthew, 1995), while another used the three bottom lines (McKenzie, 1999) and another instead used the three aspects of revenue, demand change and the efficiency of supply (Just, 2004). All of them utilised part of the concept of sustainability and focused on the balance between the multiple aspects of objectives. On the other hand, some research used the definition that rural sustainability ‘encourage[s] utilities and their customers to address existing needs so that future generations will not be left to address the approaching wave of infrastructure needs that will result from aging [sic] infrastructure’ (US Environmental Protection Agency, 2009). Here, we focused on the intergenerational equity of one aspect of the concept of sustainability.

The element shared by demographic change, the urban cycle hypothesis and sustainability as a research framework was time. When a population increases and the economy grows, a small overcapacity of infrastructure can be absorbed by demand realised later on. On the other hand, when a population declines, infrastructure always becomes inefficient, because infrastructure managers cannot respond to the change in demand quickly. Accordingly, it is important that this inevitable inefficiency should be minimised. A research framework with a temporal axis is required in order to discuss this problem.

Research frameworks such as demographic change and the city cycle hypothesis did not analyse the impact of population decline on infrastructures directly. In contrast, discussions on sustainability normally used a framework such as the triple bottom line in order to examine detailed aspects of the impact. This method was useful for achieving a balance between the various aspects and intergenerational equity.

6.3.2.2 Research methodology

The research methods followed in previous studies included literature reviews (Buhr, 2007; Hoornbeek and Schwarz, 2009; Just, 2004; Hummel and Lux, 2007), interviews (Matsuno and

Yoshida, 2008a, 2008b; Furuyama, 2007; Hoornbeek and Schwarz, 2009), questionnaires (Taira, 2005; McKenzie, 1999), and secondary data analysis (Uchida and Deguchi, 2006; Just, 2004; Hummel and Lux, 2007).

Literature reviews were conducted on the types of impact occurring in specific infrastructure sectors (Buhr, 2007; Hoornbeek and Schwarz, 2009) or on the nature of infrastructure sustainability (Hoornbeek and Schwarz, 2009).

Interviews were conducted mainly with public officers (Matsuno and Yoshida, 2008a, 2008b; Furuyama, 2007; Hoornbeek and Schwarz, 2009) and residents (Furuyama, 2007) in depopulating areas. In particular, research interviewing infrastructure managers in Cleveland, Ohio focused on regional management in depopulating and low-density areas, ideal infrastructure management in the future etc. (Hoornbeek and Schwarz, 2009).

On the other hand, only two questionnaire studies were conducted. One focused on Japanese depopulating cities (Taira, 2005) and the other focused on the rural agricultural areas in Western Australia (McKenzie, 1999). The former was conducted between June and July 2004 and the questionnaire was sent out by post and collected by post or fax. The survey was distributed to 212 municipalities and 103 municipalities responded, giving a response rate of 48.6%. Questions addressed the situation and causes of population decline, the possibility of sustaining the population, the regional problems caused by population decline and countermeasures to mitigate these problems. The latter study used a two-stage survey. The questionnaire was distributed to 312 randomly-selected addresses as a pilot survey and 42% of the questionnaires were collected in the first stage. Next, the questionnaire was distributed via the local newspaper and 20% of the questionnaires were collected. Moreover, after the questionnaire stage had been completed, in-depth interviews and a focus group survey were conducted.

Finally, secondary data analysis was a common method employed in several previous studies, addressing a wide range of issues including budget, population, the density of inhabited areas, ageing rate, infrastructure development, regional comparison of industrial ratios, data on public housing including the vacant house rate, the deterioration rate and location (Uchida and Deguchi, 2006), the analysis of demographic statistics and economic indicators (Feser and Sweeney, 1999) and a comparison between water usage and the trend in population decline (Just, 2004; Hummel and Lux, 2007). The statistics referring directly to the impact of population decline on infrastructure have not all been published, and so typically only indirect data such as demographic data, infrastructure development and financial data were analysed in previous studies.

In summary, neither a comprehensive literature review, nor sufficient field studies, nor satisfactory quantitative research has yet been conducted. For instance, many studies on infrastructure managers were found, but there were few studies on infrastructure users. Interviews used limited samples or cases, and questionnaires were administered in only two studies. More methods for primary data collection, like questionnaires, should be used because there are currently very few statistics on the impact of population decline on infrastructure.

6.3.2.3 Analytical methodology

The analytical methodologies used in the previous studies included cross-tabulation (Uchida and Deguchi, 2006; McKenzie, 1999), scoring (Taira, 2005), mapping (Uchida and Deguchi, 2006; Ujihara et al., 2007), simple linear regression analysis (Taira, 2005), time series analysis (Feser and Sweeney, 1999), the use of ecological footprints (Ujihara et al., 2007) and an infrastructure cost calculation tool (Schiller and Siedentop, 2006). For cross-tabulation, the χ^2 test was conducted in order to judge significant differences (McKenzie, 1999). The infrastructure cost calculation tool is an urban structure-type approach; estimated infrastructure costs assume the distribution of buildings in each area of urban density in a neighbourhood. This tool can address both population decline and population increase. Typically, previous studies on the costs of urban sprawl have made an assumption about the constancy of population density, but this tool is based on an assumption about the decline in density and consequent increases in infrastructure costs (Schiller and Siedentop, 2006).

These methods were sometimes combined with each other. For instance, one study combined aerial photographs and maps of roads, water supply, wastewater management and gas pipe networks. Furthermore, vacant houses and demolished buildings were also shown on the combined map. The map was used to estimate the change in infrastructure efficiency with the ecological footprint in accordance with the increase in the number of vacant houses and demolished buildings (Ujihara et al., 2007).

Apart from the ecological footprint and infrastructure cost calculation tools, basic analytical methods were previously applied to the collected data. This suggests that research on the impact of population decline on infrastructures is still at an early stage.

6.3.3 IMPACT ON INFRASTRUCTURE

In the case studies examining the shrinking cities of Liverpool, Leipzig/Halle, Timisoara, Ostrava, Bytom/Sosnowiec, Donetsk/Makiivka, closures of schools and kindergartens as social infrastructures and falling demand for water supply, heating, gas network as technical infrastructure were reported (Rink et al., 2010).

When discussing impacts of population decline on infrastructure management, the differences in consequence or phenomena and impacts or problems were discussed. Shrinking demand for infrastructure (for younger groups, like kindergartens and schools, and water, heating and public transport) was a consequence, but cuts in funding, closure of facilities, restructuring networks were problems (Hasse et al., 2012). In the following discussion, the latter problems were mainly discussed.

In order to discuss various impacts systematically, they were organised according to four aspects of infrastructure sustainability (Sahely et al., 2005). This section describes the impacts extracted from the existing literature according to four aspects of infrastructure sustainability, namely “society,” “the environment,” “economy” and “engineering.”

6.3.3.1 Social impact

The most typical reaction to population decline in depopulating areas was demolition of infrastructure (Richardson and Nam, 2014), but it was only a phenomenon, not an issue, impact or problem in itself. The social impact of population decline on infrastructure can be considered in terms of a decline in accessibility and a decline in social safety.

The decline in accessibility means that transport demand declines owing to dispersed habitation resulting from population decline (Just, 2004), and the profitability and frequency of public transport decreases due to the population decline (Buhr, 2007). In addition, the distance to commercial facilities and public administrative facilities may be greater than before because some may have been abolished and/or centralised (Hummel and Lux, 2007). Furthermore, the street network has to be adjusted owing to the change in population density, the capacity of roads has to be increased and additional investments in parking spaces are required (Buhr, 2007; Taira, 2005). Moreover, the suspension of dangerous roads such as the parallel bypass in the city of Utashinai in the winter and the downgrading of the bridge from vehicular to pedestrian access have occurred in order to reduce costs (Matsuno and Yoshida, 2008a). On the other hand, congestion in the streets surrounding schools during commuting time has decreased owing to the decline in the number of pupils (Just, 2004).

The population decline in the younger generation has resulted in the closure of schools (Roy and Matthew, 1995). Population decline correlates with an ageing population, and an ageing population requires more healthcare and medical facilities, but such facilities are sometimes unable to recruit enough medical staff (Buhr, 2007; Taira, 2005). In addition, in order to cope with population decline, municipalities sometimes like to introduce more public facilities such as educational and social care facilities (McKenzie, 1999).

In terms of social safety, the increase in the number of vacant houses owing to population decline requires these excess houses to be reorganised and demolished, and the development of attached underground infrastructure, schools and gymnasia in order to prevent squatters and increased maintenance costs (Matsuno and Yoshida, 2008b). An insufficient budget for demolition and the prohibition against converting vacant land after the abolishment of school buildings and public facilities leads to subsequent delays in vacant land sales and conversions which sometimes produce further financial deficits (Matsuno and Yoshida, 2008a; Taira, 2005).

Point-type infrastructure and transport infrastructure can be abandoned in accordance with population decline; branch networks can also be abandoned, but trunk networks in the water supply and wastewater management sector cannot (Hummel and Lux, 2007). The length of pipes has increased by 50% owing to simultaneous sprawls across urban areas when the population and water consumption have declined (Matsuno and Yoshida, 2008b). In other cases, population decline does not lead to a decline in water consumption at peak time, or a decline in the demand for the rainfall drainage and water supply for fire-plugs, and so abolishing pipe networks is almost impossible (Moss, 2008). In contrast, a huge population decline enables the downsizing (in other words, right-sizing (Hollander et al., 2009)) of the capacity of infrastructure such as filtering systems in the water supply. For instance, six water supply plants and two wastewater management plants in Berlin were suspended after reunification (Moss, 2003). In another case, the shrinkage of the service area for infrastructure was also reported (Koziol, 2004; Koziol, 2006).

Furthermore, community facilities, irrigation systems, reservoirs etc. face difficulties in maintenance (Furuyama, 2007; Ministry of Land, Infrastructure and Transport, 2007).

In summary, compared with building infrastructure, technical network infrastructures cannot adjust to population decline (Schiller and Siedentop, 2006). In particular, when the redundancy of infrastructure networks and the risks and costs of reducing existing infrastructure are taken into consideration, the rational answer is not always a reduction in response to population decline (Hoornbeek and Schwarz, 2009).

6.3.3.2 Engineering impact

Typical effects of population decline on engineering included a decline in the network efficiency (Matsuno and Yoshida, 2008b; Hummel et al., 2007), a reduction in the maintenance level (Matsuno and Yoshida, 2008a; Feser and Sweeney, 1999) and the outsourcing of maintenance to residents and user groups owing to a lack of infrastructure managers (Matsuno and Yoshida, 2008a).

A decline in efficiency was mainly reported in water supply and wastewater management (Matsuno and Yoshida, 2008b). A reduction in the maintenance level included an increase in the threshold of the accumulated snowfall to be ploughed by the municipalities, the suspension of road heating except for crossings, mowing and the emergency treatment of small troubles (Matsuno and Yoshida, 2008a) as well as the postponement of maintenance owing to a lack of funds (Matsuno and Yoshida, 2008a; Feser and Sweeney, 1999).

As mentioned above, mowing and emergency repairs had previously been conducted by municipality officers, but outsourcing can be more cost-effective for recurring maintenance works (Matsuno and Yoshida, 2008a). In this regard, elderly people promised infrastructure maintenance by municipalities and the outmigration of residents has resulted in the deterioration of the supporting system with regard to infrastructure management in depopulating areas (Matsuno and Yoshida, 2008a). Strong budgetary constraints caused by population decline have also resulted in the reduction of public officers and the lack of engineers, meaning that cooperation between municipalities and support from the central government are important in order to mitigate the impact on engineering (Matsuno and Yoshida, 2008a).

6.3.3.3 Environmental impact

The environmental impacts of population decline on infrastructure can be divided into three categories: landscape; pollution and resources and energy use.

In terms of the impact on landscape, land left vacant after the demolition of empty houses has been left derelict, causing inefficient land use resulting in deteriorating landscape and hygienic conditions (Taira, 2005). In contrast, more green fields are expected to be conserved, and landscape is also expected to be sustained because new infrastructure developments decline and replacements or redevelopments are often conducted more in a depopulating society (Taira, 2005). This can be considered a positive effect.

The positive impacts of population decline on pollution included a reduction in air pollutants, a lower pollution load owing to the decline in wastewater from households and the prolongation of the period for which solid waste landfills are useable owing to a decline in the amount of solid waste. The negative impacts included an increase in the transportation distance for solid wastes owing to waste management facilities merging to improve the efficiency in response to a reduction in solid waste in a depopulating society (Taira, 2005). In the water supply and wastewater management sector, when the number of households increases but the population density declines, the demand for water increases but the retention time also increases, meaning that additional pipe cleaning is required in order to prevent the water temperature from rising and contamination from bacteria

(Hummel and Lux, 2007; Moss, 2008). In addition, less water is drawn from underground raising the underground water level, meaning flooding may occur in the basements of buildings (Moss, 2008). Furthermore, extra flushes to remove sediments in pipes caused by a decline in wastewater, which accelerate the deterioration of the pipe, as well as odours, soil and underground contamination around underground pipes were identified in previous studies (Hummel and Lux, 2007; Moss, 2008).

Population shrinkage resulted in a decline in the consumption of water, heat and electricity (Koziol, 2004; Koziol, 2006; Hummel and Lux, 2007; Moss, 2008). For instance, water and heat consumption declined by 25% or 30% since 1990 and a population decline of more than 30% would lead to a 50% reduction in water consumption in the same area (Koziol, 2004; Koziol, 2006). On the other hand, some insist that the idea of population decline leading to a direct reduction in resource use and solving ecological problems is superficial since the number of transport trips does not necessarily decrease because of population diffusion, even in a depopulating society (Ewert and Prskawetz, 2002; Liu et al., 2003). Furthermore, the environmental burden, that is energy usage, can be more efficient by reducing part of the network in the sprawling urban areas, rather than in the well-planned urban areas in the process of urban shrinkage, as sprawling urban areas have less efficient infrastructure networks from a land, energy and resource usage perspective (Ujihara et al., 2007).

Interestingly, the environmental impacts of population decline on infrastructure were reported according to the positive and negative aspects of landscape, pollution and energy. This was not only due to population decline, but also to the speed of population decline, the dispersed population and the history of infrastructure development. Accordingly, in terms of the environmental impact of population decline on infrastructure, demographic factors such as the rate of population decline and spatial information such as the population distribution, the infrastructure network and location should be taken into consideration.

6.3.3.4 Economic impact

The economic impact of population decline on infrastructure management included an increase or decrease in the costs of infrastructure management according to demographic change and an increase in the financial burden per capita (Rink et al. 2010), leading to the secondary impact of a decline in the service level when the additional financial burden was avoided.

First, in terms of an increase or decrease in costs, a reduction in road traffic may decrease maintenance costs (Koziol, 2004; Koziol, 2006) and the merger and abolishment of public facilities may also result in a reduction in maintenance costs through the sacrifice of usability (Roy and Matthew, 1995). In contrast, there was the possibility for an increase in infrastructure costs, as the government still has to pay the maintenance costs for abandoned public facilities such as public housing and schools in order to sustain social safety and to prevent accidents from occurring under strict budgetary constraints (Matsuno and Yoshida, 2008a). The same phenomenon was described as 'operating costs increase in shrinking cities and fiscal bases are reduced' (Rybszynski and Linneman, 1999, p.221). The maintenance costs of infrastructure based on huge populations cannot necessarily be reduced in accordance with a decline in usage (Feser and Sweeney, 1999). The substitution of private bus services for public bus services in order to sustain transportation in the depopulating municipalities will increase the budgetary deficit (Taira, 2005). The expansion of the area where public transport is provided will lead to an increase in operation and time costs (Buhr, 2007; Hummel and Lux, 2007), while the ageing infrastructure typical of depopulating cities (Hoornbeek and Schwarz, 2009) means an increase in the maintenance costs of buildings (Taira, 2005). Finally, not only replacement investments, but also direct and indirect demolition costs are required when infrastructure is replaced (Just, 2004).

The increase in the financial burden per capita was often discussed in previous studies in terms of transport, water supply, wastewater management and education (Koziol, 2004; Koziol, 2006; Hummel and Lux, 2007; Taira, 2005; Just, 2004; Moss, 2008; Hoornbeek and Schwarz, 2009). In particular, part of the cost of underground infrastructures was sometimes transferred to municipalities and users when buildings were demolished (Buhr, 2007). For instance, the abandonment of a railway owing to a decline in traffic caused by population decline may lead to an increase in road traffic, in which the maintenance costs were charged to the municipalities and users, although the maintenance cost of the railway services was paid by the central government (McKenzie, 1999). Furthermore, this increase in per capita costs led to a further decline in usability (Taira, 2005) and possibly more outmigration. In this way, population decline caused a change in infrastructure service provision and also changed users' financial burden. In other words, light and widespread financial burdens could change to heavy and concentrated financial burdens.

In summary, the economic impacts of population decline had both negative and positive aspects, while per capita financial burdens inevitably rose without the dramatic reduction of infrastructure service provision.

6.3.3.5 Intergenerational equity

Few studies applied the sustainability framework to this topic, but none discussed intergenerational equity in terms of the impact of population decline on infrastructure. All of these studies showed an interest in current impacts, but none discussed the transition of the impact, the extent of the financial burden or the potential benefits. When the sustainability framework is applied in the future, intergenerational equity should also be taken into consideration.

6.3.4 COUNTERMEASURES

Infrastructures are developed by supply-side policy, but population decline brings about various changes, including the method of provision; as the demand for infrastructure cannot be estimated appropriately, new demands for infrastructure have to be created, and demand management (not supply management) is important for sustaining network efficiency. Infrastructure can be used for adjusting regional differentiation; infrastructures are not regional assets but regional debts, including the risk of an increase in the users' costs in the future (Moss, 2008). On the other hand, the characteristics of immobility and inseparability of infrastructures have remained (Hoornbeek and Schwarz, 2009). This makes the situation more complicated.

Countermeasures designed to adjust physical infrastructures with demographic changes were described (Buhr, 2007; p. 35, Table 3), but they did not focus specifically on population decline. In order to cope with the impact, several countermeasures were discussed regarding the social and engineering impact on infrastructure sustainability, taking time and space into consideration. In terms of economic aspects, an increase in user charges links readily with the decline in utility level, but such a decline can be mitigated by social and engineering countermeasures or be considered a constraint when social and engineering countermeasures are implemented. Environmental impacts are consequently often mitigated using social and engineering countermeasures. Accordingly, no obvious target is usually established when countermeasures are developed. Furthermore, not only the development of individual countermeasures, but also their integration or combination is necessary.

The service level was a social countermeasure and included the reduction of excess supply, conversion, additional service provisions and the use of the external capacity of infrastructures. Otherwise, infrastructure service was provided on-demand.

A typical example of excess supply reduction was the demolition in Eastern Germany represented by Stadtumbau Ost (Buhr, 2007). In another study, infrastructure service provisions were summarised, such as the merger of comprehensive schools with facilities in accordance with population decline (Just, 2004). Furthermore, the downsizing of the diameter of water pipes was also required from an environmental perspective (Koziol, 2006). On the other hand, the ease of conducting countermeasures varied. For example, network infrastructures such as roads were difficult to reduce quickly, but streetlights were easily turned off to reduce electricity and costs. The long-term possibility of regional development and continuous infrastructure service provision for the remaining residents made countermeasures more complicated (Hoornbeek and Schwarz, 2009). Not only should simple capacity reductions be carried out, but also conversions, such as changing education facilities into social education facilities, sports facilities and churches, barracks into public administrative buildings, public housing into nursing homes and hospitals into houses in order to compensate for the insufficient infrastructure provision and new infrastructure demands should be considered as measures (Matsuno and Yoshida, 2008b). Vacant schoolrooms can also be converted for social care purposes etc. (Taira, 2005). Additional services included: greening; developing parks; reducing the barriers to infrastructure (Matsuno and Yoshida, 2008b); developing a cable television network; developing community facilities; developing houses for the elderly; reusing vacant houses; developing agricultural and forestry roads; providing free or cheap public bus services; developing medical care in remote areas and the introduction of transportation for patients (Ministry of Land, Infrastructure and Transport, 2007). Additionally, the following can be considered: constructing public housing; improving medical care services; supporting rail transport and developing roads to improve access to neighbouring cities; subsidising bus services and shrinking residential areas (Taira, 2005). These reduce previous infrastructure capacities but develop alternative infrastructures and utilise vacant space to satisfy residential demands. Furthermore, the government usually develops infrastructure themselves, but the possibility of renting spaces for temporary public services from private owners was also discussed (Just, 2004). Moreover, the possibility that users may develop the infrastructure themselves is likely to break the natural monopoly of infrastructure provision held by the government (Moss, 2008).

After demolishing infrastructure capacity completely, the on-demand infrastructure service like "Royal Flying Doctor Service" was provided instead of sustaining partial infrastructure service (Böhm, 2006). The idea was 'infrastructure services do not need to be constantly available at fixed points, but only at the time and place needed' (Böhm, 2006: p.238). In fact, the on-demand public transport system can easily be found in depopulating regions in Japan. Therefore, this idea must also be a valuable solution for depopulating areas.

On the other hand, engineering countermeasures included reviewing the maintenance level, reducing costs by outsourcing maintenance works and introducing engineering asset management, but no technologies or strategies for reducing the costs of infrastructure demolition could be found. Therefore, it was hard to reduce the fixed costs of infrastructures in accordance with population decline (Hoornbeek and Schwarz, 2009).

Reviewing maintenance levels was mentioned previously, as was reducing the frequency of snow ploughing and cleaning. Outsourcing was conducted not only by private engineering companies but also by volunteers and residents (Matsuno and Yoshida, 2008a). On the other hand, long-term infrastructure management with engineering asset management was discussed from both the positive side, highlighting the necessity of its introduction (Hoornbeek and Schwarz, 2009), and the negative side, citing the difficulty of introducing it because of the lack of engineers and the poor understanding of the financial departments of municipalities (Matsuno and Yoshida, 2008a).

The discussion regarding a temporal axis highlighted the necessity of considering infrastructure provision for a limited period based on the population decline trend (Buhr, 2007). In addition, the temporal axis was important when an infrastructure provision plan is established which takes into account the speed of population decline and budgetary constraints (Taira, 2005). Regarding concrete countermeasures, on the one hand, the expansion of service provision areas of water supply and wastewater management can utilise the excess capacity of infrastructures over a shorter period, but on the other hand, the introduction of engineering asset management, coordination across infrastructures, smart technology and the utilisation of vacant lands and houses can be considered a long-term solution to transition into (Hoornbeek and Schwarz, 2009).

The idea of using spatiality included the partial demolition of vacant dwellings, that is, demolishing only the upper floors and edges, in contrast to demolishing a whole house. It also meant that demolition was conducted mainly in peripheral urban areas (Matsuno and Yoshida, 2008b). The same logic can be applied to network infrastructures. For instance, the demolition of peripheral water pipe networks can improve network efficiency, but demolishing the middle section of networks may sometimes diminish the overall efficiency of the network (Koziol, 2006). Furthermore, the importance of urban area reorganisation was also described; that is, attempts have been made to redistribute public houses in dispersed urban areas in a linear fashion where there were convenient forms of public transport close to commercial facilities, in order to improve the efficiency of infrastructure service provision (Uchida and Deguchi, 2006). Moreover, the usual slogan, ‘More green, less density,’ was not appropriate in depopulating areas, and the reorganisation of lower-density urban areas so that their density increases was recommended from an infrastructure management perspective (Schiller and Siedentop, 2006).

The combination of these countermeasures was also proposed. For example, the necessity of integrating both network infrastructure downsizing and housing demolition was mentioned because large-scale demolition has much better results than pinpoint demolition (Just, 2004). In addition, larger cities should downsize and infrastructure development should utilise existing infrastructures to harmonise with the natural environment and artificial green spaces, and consequently the quality of life and nature should improve (Tanbo, 2002). Several kinds of infrastructure can also be grouped together. For example, once pavements are removed, rainwater easily penetrates the soil, and so drainage is not required. Increasing dependency on public transport reduces energy consumption, and controlling water supply service areas can also reduce water distribution energy costs (Hoornbeek and Schwarz, 2009).

The countermeasures for the impacts of population decline sometimes affected the organisation of local governments. For example, ‘the city has been attempting to influence or control the provision process of the social infrastructure system (kindergartens, schools, elderly care facilities, etc.), through a combination of administrative and organizational change, geographical concentration of such facilities accompanied by qualitative improvements of services, etc’ (Richardson and Nam, 2014: p.257). This suggests that the re-organization of local government can be considered one of the considered solutions for mitigating impacts of population decline on infrastructure management.

Moreover, comparable analytical indicators on the impacts of shrinkage on technical infrastructure were also developed. In order to analyse the research questions of “how does shrinkage impact the demand for utilities and technical infrastructure?”, “is oversized infrastructure a problem?”, ” how do cities adopt to changing demands for technical infrastructure?”, the following indicators of “supply structures (length of pipes per capita etc.)”, “demand for technical infrastructures”, “new development, maintenance, improvement activities”, and “demolition/deconstruction of technical infrastructure” were set as indicators for the challenges of “oversized infrastructure, falling demand”, and “costly adjustment, due to high share of fixed costs”. These indicators can be also used for the conditional monitoring of impact occurrence of population decline on infrastructure (Rink et al., 2009).

These countermeasures were, in short, attempts to adjust temporally and spatially inflexible infrastructures to sequential changes in demand caused by population decline. Finding ways for the infrastructure to follow these changes in a flexible manner is key to infrastructure development and management in a depopulating society.

6.4 Concluding remarks

This chapter comprised a literature review of the impact of population decline on infrastructure development and management. Consequently, the following points were made.

First, in terms of demographic factors, a large but slow population decline was unlikely to have a significant impact. On the contrary, a small but rapid population decline may have an impact on infrastructure development and management. Accordingly, the speed of population decline was a key issue. Both natural decline and social decline owing to decreasing work opportunities can have an impact.

Few previous studies took into account geographical factors in their discussion of the impact of population decline on infrastructures, because there is so little variability in the terrain in Eastern Germany, Western Australia and the Midwest in the USA, unlike Japan. In addition, most of the studies focused solely on urban areas or rural areas. Accordingly, there was no discussion of the differential impact on urban and rural areas.

Almost all types of infrastructure were discussed, except anti-disaster facilities such as dams and levees and some transport infrastructures like airports and ports. There are many anti-disaster facilities in Japan, and they are located in depopulating areas, and so they should be included in future research.

As a research framework, the concept of sustainability can be considered as the best way to discuss the topics relating to the impact of population decline on infrastructures because it includes three or more subcategories for the objective and also encompasses the element of intergenerational equity. This means that discussion can be carried out based on a temporal framework.

Most of the previous studies were field surveys, using interviews and case study approaches. Only two previous studies conducted questionnaires. Nevertheless, they used relatively simple analytical methods such as descriptive statistics, cross-tabulation etc.. In order to discuss this topic comprehensively, wider and more detailed research is necessary. Accordingly, future researchers should consider obtaining more data and using more complicated analytical methods.

Previous studies have reported a decline in the usability of infrastructures, the deterioration of regional safety, a reduction in the maintenance level, an increase in the financial burden per capita and both decreases and increases in the environmental burden as impacts of population decline on infrastructures. However, a discussion on intergenerational equity could not be found.

Not only individual countermeasures, but also the combination or integration of individual countermeasures was mentioned, as was the significance of temporal and spatial perspectives. These were, however, mere allusions and no comprehensive or integrated research idea has been presented until now.

In the light of the aforementioned findings, it is fair to say that research on the impact of population decline on infrastructure is still in its early stage. The importance of region-specific research was pointed out (Schiller and Siedentop, 2006), as well as the necessity of more holistic and inter-temporal surveys (Matsuno and Yoshida, 2008a; Uchida and Deguchi, 2006; Ujihara et al., 2007). In addition, the necessity of countermeasures for individual infrastructures as well as the development of improved social systems designed to cope with this issue was highlighted (Tanbo, 2002). Comprehensive but fundamental research is needed in the future.

As pointed out, 'it has been difficult to provide a clear and comprehensive picture of the impact of shrinkage on technical infrastructure, mainly due to the lack of comparable data for water and waste water supply and central heating' (Rink et al., 2010).

These discussions on infrastructure were mainly based on the managerial perspective, but users' opinions and reactions are also important. As mentioned in previous studies, residents in depopulating regions have suffered from a decline in infrastructure service provision. Governments have limited budgets, and the balance between benefits and financial burdens is a significant research topic. Regrettably, no research has yet been conducted on this point.

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CHAPTER 7: INTERVIEW：THE CAUSES OF POPULATION DECLINE AND ITS IMPACTS ON INFRASTRUCTURE MANAGEMENT: A CASE STUDY IN HOKKAIDO, JAPAN[3]

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7.1 INTRODUCTION

Previous research into population decline and its impacts on infrastructure seems to have been conducted using literature reviews and secondary data analysis (Tanbo, 2002), as opposed to field surveys and empirical data, particularly in Japan, although some field research and empirical studies have been conducted in the United States, Australia and Germany, as noted in the chapter on our literature survey. As a result, the extent of the impact of population decline on infrastructure is still unclear in Japan.

This chapter investigates the extent to which population decline influences infrastructure management in Hokkaido, Japan, following a stepwise procedure using statistics and the history of the municipality. Analysis of secondary data sources confirms findings from interviews with experts in the field.

International comparisons are also conducted in order to better understand the case in Japan. The study adds to what is a very limited body of evidence on the relationship between population decline and infrastructure.

The structure of this chapter is as follows: Section Two describes the case study of Hokkaido, including the methods used to select the case study areas and the central features of those areas; Section Three presents the methodology; Section Four describes the findings regarding the effects of population decline on infrastructure management and the results of the international comparisons; and Section Five concludes with a discussion, and the implications, of the findings.

7.2 CASE STUDY AREAS

The city of Muroran (population greater than 50,000), the town of Iwanai (population greater than 10,000 but fewer than 50,000) and the town of Minami Furano (population fewer than 10,000) were selected because they represented the most severe population decline in each population category. They are all located on Hokkaido Island in Japan, as shown in Figure 68.

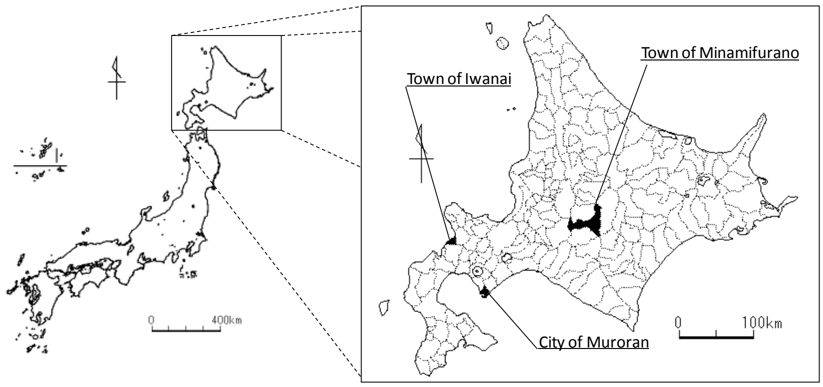


Figure 68 Location of municipalities surveyed

7.3 METHODOLOGY

7.3.1 SELECTION OF OBJECTIVE MUNICIPALITIES

The extent of population decline is a significant factor when discussing its impact on infrastructure. The size of the population in a municipality is also important because the smaller the population, the greater the impact of population decline on infrastructure for the same amount of infrastructure closure. Accordingly, this survey focused on three representative areas of main local government (municipalities) in Japan: a city, a town and a village. It was assumed that, because municipalities provide fundamental public infrastructure services, they would be strongly affected by population decline. The infrastructure managed by the state and the prefectures plays a major role in the infrastructure network, and has to be maintained irrespective of the level of the population. In addition, municipality officers usually live in the region, which allows researchers to obtain resident perspectives in order to support their data. The municipalities oversee the municipal corporations and also include private utility companies, such as regional electricity corporations like the Hokkaido Electric Power Corporation.

The causes of population decline are also important. Population decline in Japan is natural, caused by a falling fertility rate. It is important to distinguish this long-term population decline from short-term forms of population decline (such as that witnessed in mining areas), because including the latter in a list of potential cases for the present study would lead to overestimation of the impact of population decline on infrastructure in the future. The methodology used to consider the interview results will be important for future comparison studies. The character of municipalities is naturally different, and the situations are expected to be different according to other conditions. Subjectivity and selection bias should be avoided when selecting cases for study. An objective method for selection of the case study municipalities was, therefore, employed as follows. Three factors were used as filters when the case study areas were selected from a list of municipalities in Japan: population size, the rate of population decline and the cause of population decline.

Using national census data from the year 2000, Japanese municipalities were divided into three categories: those with fewer than 10,000 people; those with between 10,000 and 50,000 people; and those with more than 50,000 people. The 10 municipalities with the highest rate of population decline were selected from each category; those which had experienced mine closures and municipality mergers were excluded.

7.3.2 OBJECTIVES OF INFRASTRUCTURE AND ITS IMPACTS

The definition of infrastructure and of impacts is the same as introduced in Sections 2.3 and 2.4 respectively. In addition, the municipality level of infrastructure is focused on. This is because the central government and prefectural governments both develop and manage infrastructures, but these infrastructures also have another function, to link the regions. Even if the population declined in some regions, the infrastructure should be supported until the central or prefectural government faces severe budgetary deficits as a result. It is currently still affordable for the central and prefectural governments to sustain regional infrastructures, which suggests that it may be difficult to find any notable impact on infrastructure development and management at this level. This study, therefore, focuses on the municipality level of infrastructures.

7.3.3 SECONDARY DATA

This research also uses secondary data on general construction investment, maintenance costs, the standard level of general income and ordinary balance rates between general revenue and expenditure from *Shi Chou Son betsu Kessann Jyoukyou Shirabe* (a survey of the financial results in each municipality) (Ministry of Internal Affairs and Communications, 1970-2012), and demographic data from the national census, which has been conducted every five years since 1970 (Ministry of Internal affairs and Communications, 1970-2010) .

7.3.4 Interviews

7.3.4.1 Methodology

Face-to-face semi-structured interviews were conducted with experts, using open-ended questions and pre-set questionnaires. The interview process was recorded and official proofs of the interviews were then produced, in the form of abstracted transcriptions of the records which were confirmed by the interviewees. For reasons of brevity, the full content of the interviews is not presented in this chapter.

In addition, in order to triangulate the interview results from before and after the interviews, the actual situation of infrastructure was observed by driving a car through the municipalities. It was thus confirmed that there were no unlikely responses from the interviewees.

7.3.4.2 Selection of interviewees

In Japan, as described in Chapter 4, municipalities are responsible for several types of infrastructure development and management. All municipalities have dedicated departments for infrastructure development and management, but in addition a few departments are in charge related to cross-section. For example, the education department is in charge of school facilities, the civil engineering department is in charge of road, bridge and tunnel construction and maintenance, and the water bureau is in charge of drinking water infrastructure. These dedicated departments are in charge of planning and practical work, but the planning division also provides single window service to deal with external enquiries. In some municipalities, the planning division also has the responsibility for coordinating several departments in charge of infrastructure development and management. For this study, the planning division is chosen as the contact when considering this Japanese form of organisation. Contacting the planning division has another merit: they have comprehensive information about the municipalities including about the budgetary situation, demographic change, industrial development, and so on. Contact with this division is therefore expected to result in more objective information than would contact with each individual department having responsibility of separate types of infrastructure.

Accordingly, the interviewees were generally from the planning division, although the officer in the Muroran planning division invited other officers from the civil works department. The contact officers circulated the questionnaire to the dedicated departments for each type of infrastructure, and answered and explained the results on behalf of the dedicated officers.

7.3.4.3 Schedule

Three interviews were conducted between May 7th and 9th, 2008. The interview in Minami Furano was held on May 7th, that in Muroran on May 8th and that in Iwanai on May 9th. Each interview lasted for one or two hours, at the municipality office.

7.3.4.4 Questionnaires

The questions asked in the interviews are shown in Table 30. Questions 1, 2, and 3 were asked in order to elicit information about how population decline had occurred. In particular, causes and timing were clarified in the interviews, in the light of knowledge from previous research. This time, the event didn't include ageing and gradual outmigration such as moving to higher education and finding jobs, because the young must leave the municipality where work opportunities are inadequate for the working-age population. This type of outmigration can be considered socio-natural demographic change. The fourth question asked about the relationship between population decline and investment in infrastructure. Was population decline considered a reason to reduce investment or a reason for investing much more, and what happened as a result? Question 5 sought to establish the criteria relating to complaints and accidents, and how problems were defined by the municipalities. The sixth question asked about the mayor's awareness of population decline, in order to consider leadership performance. Questions 7 and 8 sought resident responses to potential changes in the level of infrastructure service provision, and determined whether the municipality had any special system in place for changing levels in the provision of infrastructure. Finally, Question 9 explored the impact of population decline on infrastructure in each sector.

Table 30 Interview questions

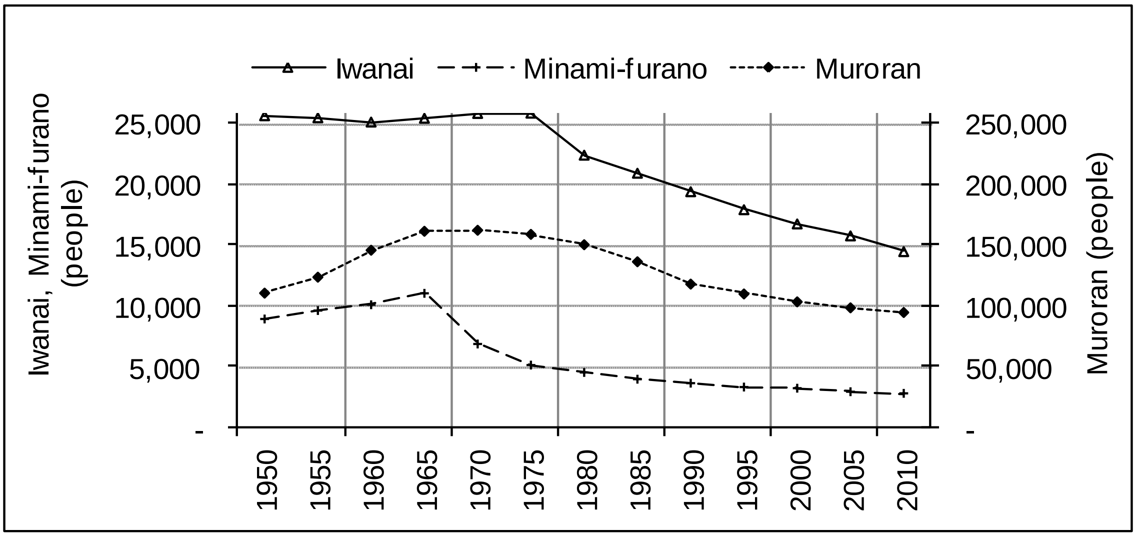
	Enquiries
1.	In what ways has population decline been observed in your municipality?
2.	When did the influence of population decline become problematic?
3.	What event caused population decline in your municipality?
4.	How did the municipality control infrastructure outlay during previous population decline?
5.	What, in relation to complaints and accidents in particular, defines a 'problem' as judged by the municipalities?
6.	Is the mayor of the municipality aware of the impact of population decline on infrastructure management?
7.	How should the municipality consult with residents when the level of infrastructure provision is to be changed?
8.	Does the municipality have any special rules or systems in place for when the level of infrastructure provision changes?
9	Have any of the following situations occurred? ・ Reduced usage of infrastructure ・ Reduced revenue ・ Increased user charges ・ Lower maintenance levels ・ Cessation of maintenance in some areas ・ Redistribution of infrastructure ・ Reduction in infrastructure ・ Abolition of infrastructure but not its demolition or the abolition of infrastructure ・ Increase in complaints about infrastructure management by users ・ Lower provision and management level causing further decline in usage ・ Lower maintenance level causing a reduction in safety, comfort and convenience ・ Improvements, e.g. reduced congestion, fewer accidents and mitigation of environmental problems

7.4 RESULTS

This section describes the interview results linked to the four aspects of infrastructure sustainability, and explores the differences between infrastructure types. A comparison between international experiences and the findings of this study is also conducted.

7.4.1 DEMOGRAPHIC CHANGE OF THE CASE STUDY AREAS

The three case study areas have experienced population decline since 1970 (Figure 69). Industrial decline, the so-called *Tetsu Bie* (iron industry decline), was the cause of population decline in Muroran. A 200 mile restriction on sea fishing caused the population to decline in Iwanai. The end of a huge infrastructure project (dam construction) in the 1970s, and branch office closures of the national railway and national forest management resulted in population decline in Minami Furano. Following these rapid declines in population, the selected municipalities experienced further long-term gradual population decline.



Source: Ministry of Internal Affairs and Communications, the Statistics Bureau and the Director-General for Policy Planning (1950-2010)

Figure 69 Population trends in the municipalities

Current population decline is gentler than those 20 years ago and all interviewees in three municipalities explained that current population decline is caused by the outmigration of young people to find the jobs and natural ageing in the interviews.

Interestingly, as described later, the municipalities developed their infrastructure after the rapid population decline. The problems of infrastructure management caused by population decline should be, therefore, considered not only over a short period of population decline, but also for long-term population decline in these areas.

7.4.2 SUSTAINABILITY

7.4.2.1 Social aspects

As mentioned above, social aspects include social safety and the accessibility (time and/or distance) of infrastructure. Obvious impacts of population decline were reported in the port (point-network type) and government administration building (point type) sectors. Population decline and economic distress resulted in the suspension of a ferry service and the reduced availability of port facilities (Iwanai). In terms of government administration buildings, there are some cases in which old buildings that do not meet anti-earthquake criteria are still used (Iwanai), branches have merged (Muroran) and branches in abandoned settlements have closed. These cases suggest that the physical safety and accessibility of governmental services are under threat.

On the other hand, officers did not report any noticeable impact of population decline in the other infrastructure sectors. This is because when demand for infrastructure declines, capacity can be reduced. For example, a water-filtering plant was closed down in order to reduce costs, but a water pipe connecting the settlement to a neighbouring one was constructed, and the service level for the residents did not change (Minami Furano). The capacity of the total water facility was reduced when a facility had to be replaced (Muroran and Iwanai). Elementary schools, nurseries and kindergartens were also closed owing to a decline in the number of students.

Public housing differ from other public buildings. Even when a population is declining, the vacancy rate of public dwellings can remain very low due to an ageing population and lower salaries in the region (Muroran). Iwanai's public dwellings are facing over-capacity because of a fire which occurred in 1954. Here, 60% of dwellings are scheduled for demolition (Iwanai). Many social education facilities are also managed by municipalities. Some should be demolished in order to save money, and relocated to other facilities in neighbouring municipalities. In this case, the need to reach an agreement with residents about the closure of excess facilities is recognised as necessary for the future by officers (Iwanai).

The situation regarding urban parks appears to be slightly different from that of other types of urban infrastructure. This is because they are officially located in the urban master plan, meaning that it is difficult to abolish them. In addition, when private developers build urban parks as the public space in their developed areas, they can donate them to the municipalities. This results in an increase in the number of urban parks even in the face of population decline (Muroran). The municipalities are limited to reducing playing facilities in urban parks and requesting that residents maintain the parks (Muroran and Iwanai).

7.4.2.2 Environmental aspects

The chosen sites were located in rural areas with no congestion problems or landscape issues, so no significant environmental impacts were observed.

7.4.2.3 Engineering aspects

Engineering impacts can be considered in terms of a decline in the maintenance level and number of in-house engineers. In contrast to other aspects of sustainability, engineering impacts (notably maintenance issues) were reported more frequently. For example, the simplified road paving used during periods of economic distress has long required attention (Muroran).

The period between inspections and maintenance is longer than it has been before, but less regular maintenance may still satisfy the minimum level required for residential areas (Muroran). In terms of snow ploughing, the level at which ploughing is required has increased from 5cm to 10cm (Muroran), and the areas which are ploughed have been reduced (Iwanai). The former is an adjustment to the service level, and the latter is a response to requests from elderly residents who object to the piles of snow that accumulate after ploughing (Iwanai). Consequently, it seems that problematic engineering impacts are relatively infrequent.

7.4.2.4 Economic aspects

Notable economic impacts, including an increase in user charges, are often reported in wastewater management, the social care sector and the education sector (Minami Furano and Muroran). Municipalities have, however, prevented an increase in the financial burden for users in several ways. For example, advanced repayments were stopped in order to absorb the potential increase in user charges for wastewater management (Muroran). In another municipality, the properties owned by the municipality were sold to private entities in order to reduce maintenance costs and to obtain property tax. Such sales also encourage private companies to develop those properties, thereby creating jobs (Minami Furano). In another case, the standard of athletic facilities was allowed to decline and an under-used gymnasium was demolished in order to save costs (Iwanai). Consequently, it can be said that potential economic impacts are prevented by the good management of municipality officers.

7.4.2.5 Intergenerational equity

Interviewees in the municipalities surveyed in this research did not recognise any issues of intergenerational equity, such as the balance of the financial burden between the current generation and future generations. There is a possibility that intergenerational equity may be achieved naturally from the revenue system of grant-in-aid from local tax revenues, as discussed below.

7.4.3 INFRASTRUCTURE SECTOR

When the interview results were reviewed, it was found that public dwellings suffered as a result of population decline, and that reorganisation and demolition were considered as possible solutions. Municipalities in Hokkaido built many public dwellings in order to cope with rapid increases in the population in the era of strong economic growth in the 1960s, but they are narrower and of poorer quality than recent public dwellings. Currently, there are many vacant public houses and buildings, and municipalities intend to keep them vacant in order to correct the gap between supply and demand. The cost of demolition could not be ascertained for all the municipalities surveyed, but, given that reorganisation takes a long time, the current high level of vacant public dwellings is not seen as a major problem.

Population decline has less of an impact on disaster-prevention infrastructure and industrial infrastructure in this region. This is because disaster-prevention infrastructure is necessary, irrespective of the population size, in the protected area. In addition, important disaster-prevention infrastructures are built and maintained by central government, and municipalities can only conduct outsourced management. Furthermore, it is not population decline but rather natural disasters that destroy these parts of the infrastructure, and this is beyond the scope of this chapter.

On the other hand, investment in industrial infrastructure is not affected by population decline; it is intended to prevent it. Consequently, investment trends for industrial infrastructures using debt financing sometimes show a negative correlation with population decline in the short term. This means that the greater the investment in infrastructure, the worse the situation will become because there will be fewer local people to repay the debt in the future.

In terms of other types of infrastructure, all three municipalities suffer from an annual population decline of around 1%, which may suggest obvious impacts on infrastructure, although none were reported by the officers. In addition, the officers in the three municipalities did not see a direct link between population decline and infrastructure development and management. In conclusion, the impact of population decline on infrastructure can be regarded as acceptable, in other words, not a severely problematic situation, which is contrary to the results of previous research. The possible reasons for this are discussed in the following section.

7.4.4 Comparison between Japan and the USA, Germany and Australia

A comparison of the results of the present study with international trends indicates that the impact observed in Japan is less pronounced, in spite of the magnitude of the population decline in Japan.

For instance, compared with German examples, the ‘cold spot’ problems experienced by network-type infrastructures such as water supply and wastewater management (see Moss, 2003, 2008) were not observed in the Japanese results. Indeed, in the case of Iwanai, a huge decline in the demand for water was reported as a result of the abolition of a ferry service, but, because the port is located at the end of a water distribution pipe network, the filtering facilities and the water supply facility have simply been downsized to adjust to this change in demand. Accordingly, the municipality anticipated and addressed a potential problem before the problem occurred.

Similarly, in Germany, increases in the user costs of transport and utility services were observed (Just, 2004). Government investment in German education cannot be reduced, however, because local politicians have prioritised spending on education (Just, 2004). In contrast, the merging and closure of schools, along with public dwellings and offices, is common in Japan. For example, the town of Iwanai reduced the number of engineers in the water supply sector. A similar situation has been noted in Germany (Just, 2004).

The factors underscoring population decline in the US are different from those in Japan. In the US, technological innovation and growth in the agricultural sector have promoted population decline in the regions affected (Feser and Sweeney, 1999). In contrast, Japan’s ageing population is the main cause of the natural population decline in rural areas. Consequently, farmers have had to expand production, introduce high-technology machines for cultivation and utilise vacant fields. While both the US and Japan share the phenomenon of population decline caused by industry decline or mine closures, the deterioration of the fiscal basis in municipalities (Feser and Sweeney, 1999) is a characteristic unique to the US. These differences are largely associated with Japan’s revenue transfer system.

In Australia, most areas have suffered a 20% population decline over the past 35 years, which is half the population decline observed in Japan. Nevertheless, as families have been forced to move to cities so that children can pursue higher education, Australia seems to have suffered severely as a result. This is likely to be associated with the country’s peculiar features of population density and infrastructure distribution.

The present study observed similar impacts as previous Japanese research (Taira, 2005), such as merged facilities and the movement of medical facilities, increased maintenance costs, reduced public administrative services, congestion mitigation, a reduced environmental burden and falling property prices.

A summary of the comparison is shown in Table 31. The factors mitigating the impact of population decline on infrastructure management found in this research do not seem to have been observed in previous case studies in the US, Germany and Australia.

Table 31 Comparison of the impact of population decline on infrastructure management across countries

Previous research results		Interview results
Australia (rural: thin) (Mackenzie, 1999)	· Separation of families because children go to school in an urban area owing to the closure of schools in rural areas · Increase in the risk of traffic accidents due to increase in lorry traffic caused by the abandonment of railways	· Students have to travel for an hour to get to school even before the merging and closure of schools · No traffic change owing to population decline and the abandonment of railways
Germany (urban: dense) (Moss, 2003, 2008; Just, 2004; Koziol, 2004; Hummel & Lux, 2007)	· 'Cold spot' problems (reduced efficiency in particular parts of the network infrastructure) · Increase in the user burden for transport and utility services · Investments in education strategically maintained	· No 'cold spot' problems · Increase in the burden on residents · Merging and closure of schools
US (rural: dense) (Edward & Stuart, 1999)	· Social population decline owing to evolution of technology · Lack of funds for infrastructure management owing to population decline	· Natural population decline owing to ageing and lack of successors · Tax revenue transfers mitigate the impact of population decline

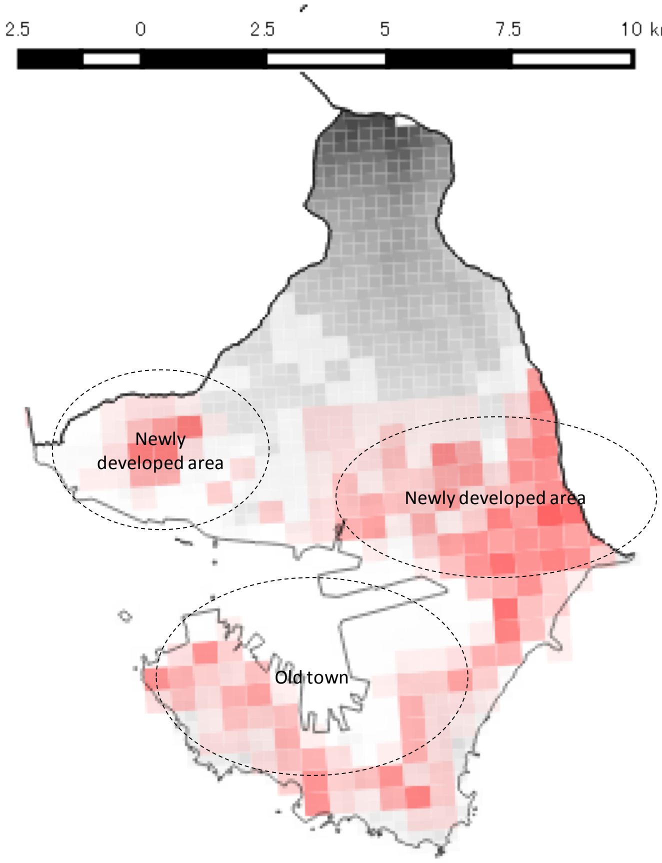
7.5 Discussion and analysis

The present study found that the observed impact of population decline on infrastructure was lower than anticipated. Instead it appears that there is a contradiction between the responses from the interviewees and what actually happened in infrastructure development and management, such as school closures in the three depopulating municipalities. In order to understand this apparent contradiction, several reasons must be considered: the strong constraints of geography, continuous administrative reform, and financial support for local municipalities from the central government.

7.5.1 Mitigation by strong geographical constraints

The case study locations, the city of Muroran, the town of Iwanai and the town of Minami Furano, all have limited habitable land owing to their mountainous terrain. The habitable areas are thus divided into compact domains with no sprawl.

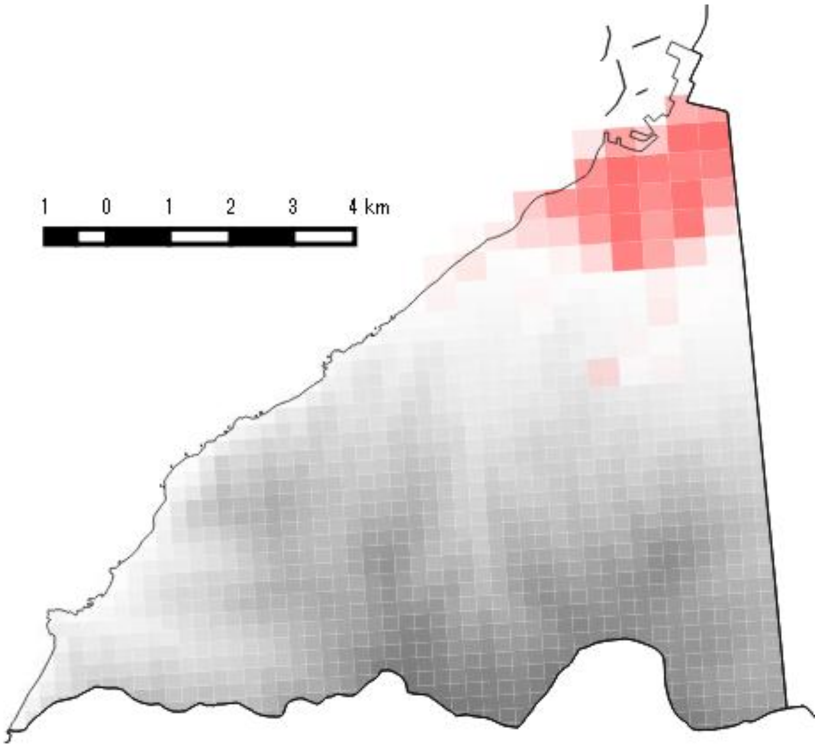
The city of Muroran is located on the hillside of Mt Muroran, near the port. The original town is near the port, but the population concentration is shifting towards the newly-developed areas in the northern part of the city (Figure 70).



Source: Ministry of Internal Affairs and Communications, the Statistics Bureau, and the Director-General for Policy Planning (2010), and Ministry of Land, Infrastructure, Transport and Tourism (2010) for National Land Numerical Information (slope, population and municipality boundary data)

Figure 70 Terrain and population distribution of the city of Muroran

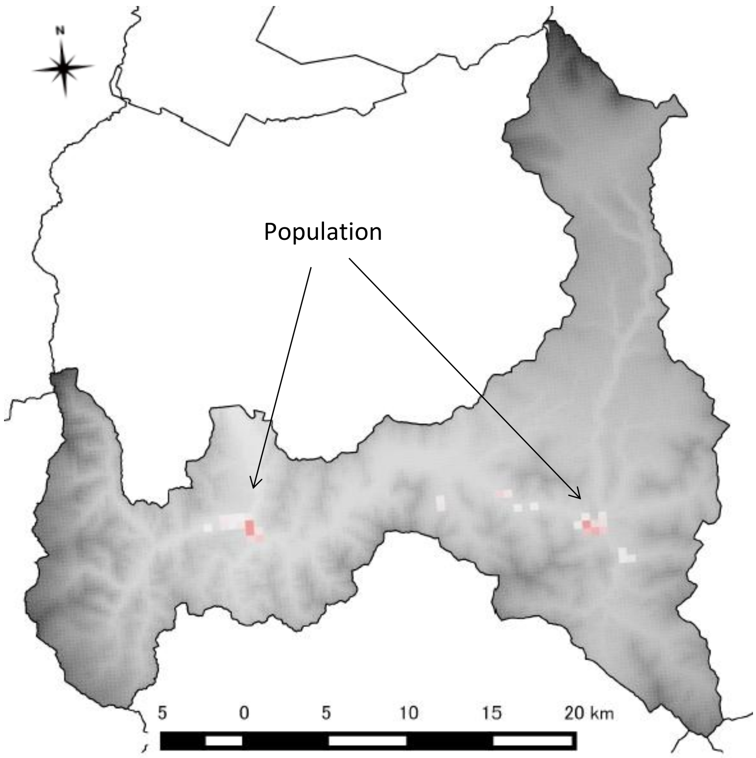
Iwanai is also located on a hillside, and the city centre is in a very small, handkerchief-like plain within the town area. Most of the land is not suitable for habitation. The town does not have any rail connections with other main towns, but relies on buses for public transport (Figure 71).



Source: Ministry of Internal Affairs and Communications, the Statistics Bureau and the Director-General for Policy Planning (2010), Ministry of Land, Infrastructure, Transport and Tourism (2010) for National Land Numerical Information (slope, population and municipality boundary data)

Figure 71 Terrain and population distribution of the town of Iwanai

The town of Minami Furano is located in a mountainous area. It has a large dammed lake named Lake Kanayama. The trunk railway passes through the town, but the number of passengers is not significant. The population is concentrated in the city centre, Ikutora, and there are not many residents in other areas (Figure 72). The infrastructure systems of all three towns have been developed to be compact, and such compactness could help to maintain the efficiency of infrastructure management. In fact, the compact infrastructure system observed in the town of Minami Furano leaves no room for further improvement because of the scattered town structure with concentration of population distribution in each settlement.



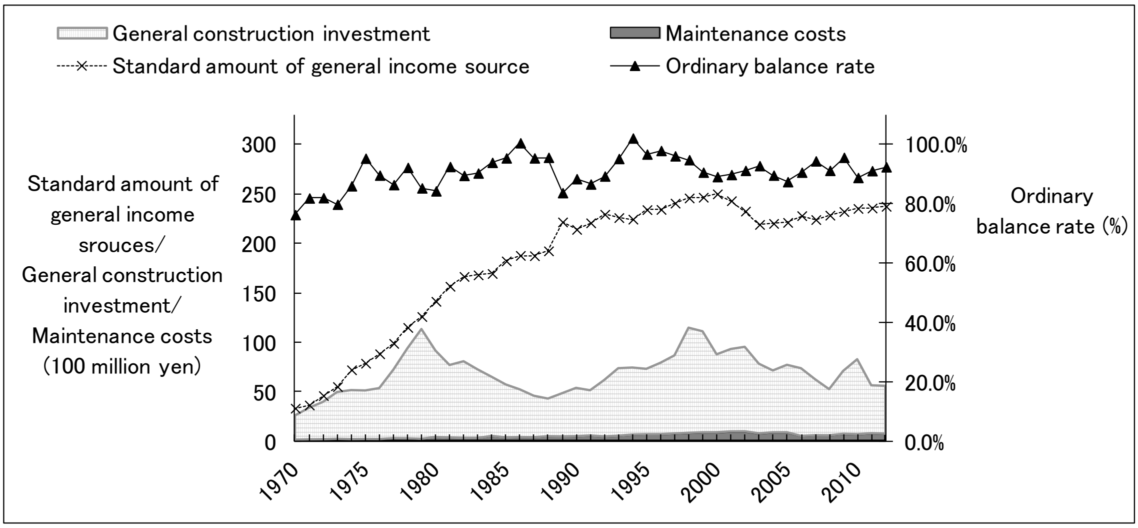
Source: The Ministry of Internal Affairs and Communications, the Statistics Bureau and the Director-General for Policy Planning (2010), Ministry of Land, Infrastructure, Transport and Tourism (2010) for National Land Numerical Information (slope, population and municipality boundary data)

Figure 72 Terrain and population distribution of the town of Minami Furano

7.5.2 CONTINUOUS ADMINISTRATIVE REFORMS

The city of Muroran has made an effort to promote administrative reform since 1975. The town of Iwanai has changed its policy in an attempt to restructure its economy. Researchers should thus also consider the local government's financial situation, because infrastructures are normally financed by local government bonds and supported by locally allocated taxes. In order to review the financial situation during the period of population decline, this study used the standard amount of general income resources, ordinary balance rates between general revenue and expenditure, general construction investment in infrastructure and the maintenance costs for infrastructure from the 1970s until 2012. It is noted that the local government financing on general income resources were introduced in the chapter four. The first two indices show the size of the economy in the municipality. The data is nominal.

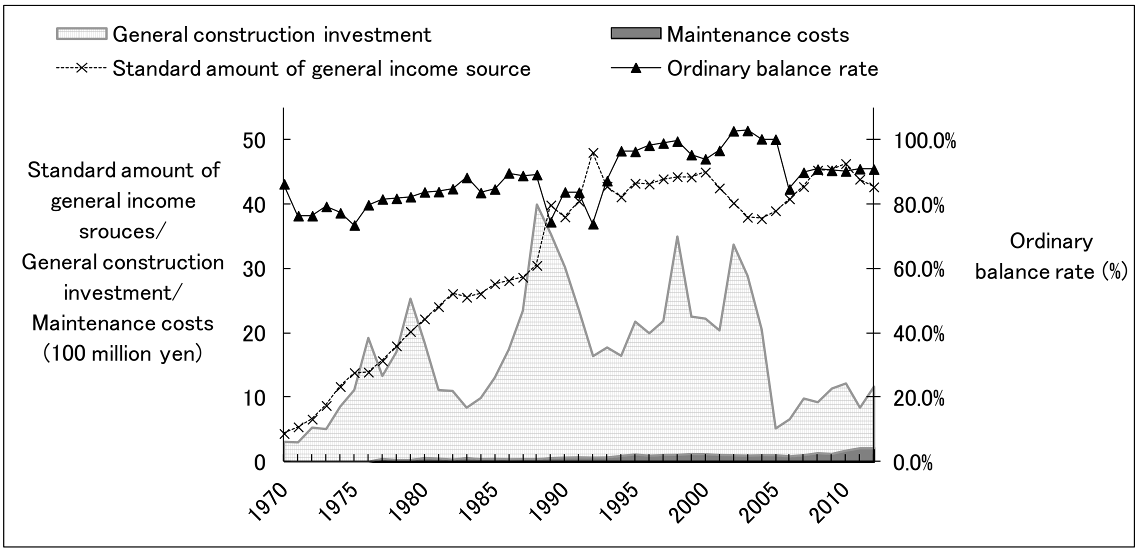
The standard amount of general income source expanded between 1970 and 2000 in Muroran, although general construction investment reduced after 1979 (due to the oil crisis). General construction investment increased again after 1989 and peaked in 1999. There is therefore no direct relationship between population decline, general construction investment and the standard amount of general income (Figure 73).



Source: Ministry of Internal Affairs and Communications (1970-2012)

Figure 73 Trends in infrastructure development and management costs and the financial situation in Muroran

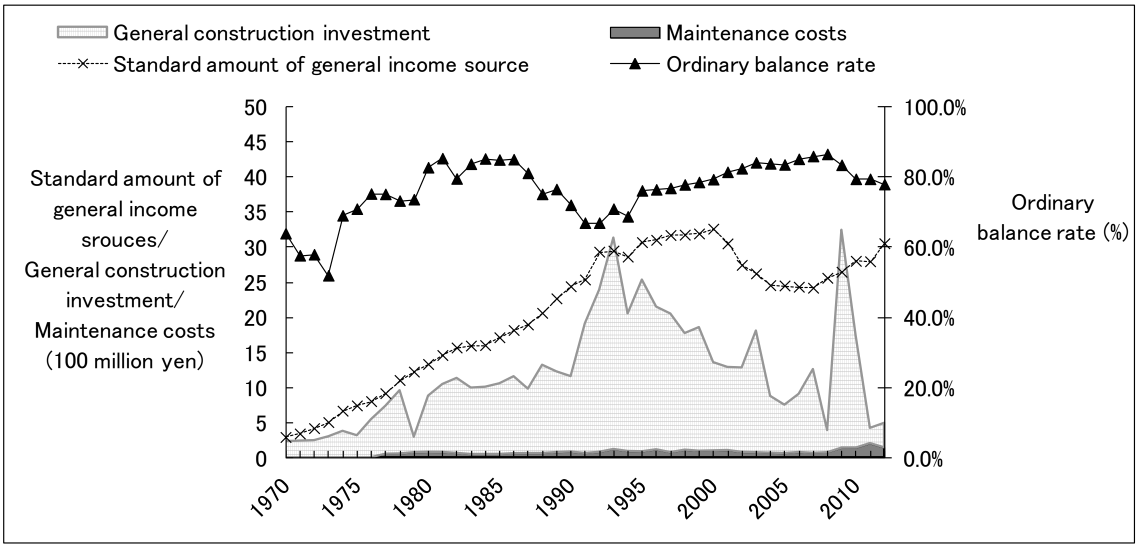
In Iwanai, the standard amount of general income source grew year on year until 1990, and has been almost stable since 1992. General construction investment decreased in 1983 but increased again after 1988. The ordinary balance rate improved occasionally in Japan's bubble economy because the local tax revenue increased, but, since then, general construction investment has been increased several times in order to boost economic revitalisation. The rapid reduction of general construction investment after 2002 resulted in an improvement of the ordinary balance rate in 2006 (Figure 74).



Source: Ministry of Internal Affairs and Communications (1970-2012)

Figure 74 Trends in infrastructure development and management costs and the financial situation in Iwanai

The standard amount of general income source and general construction investment in Minami Furano increased continuously until 1993, but general construction investment reduced at a faster rate than the standard amount of general income. The ordinary balance rate between general revenue and expenditure remained at a lower level than those of Muroran and Iwanai, indicating that the economy of Minami Furano was comparatively healthier (Figure 75).



Note: The general construction investment in 2010 was for agriculture sector and that in 2011 was for education sector.

Source: Ministry of Internal Affairs and Communications (1970-2012)

Figure 75 Trends in infrastructure development and management costs and the financial situation in Minami Furano

Such efforts to control the budget conditions may have mitigated the problems caused by population decline. In fact, the municipalities surveyed here have reduced the public facilities which are easily affected by demographic change in terms of the timing of their replacements. The reductions do not represent a decline in the infrastructure service level, merely an adjustment designed to meet the needs of a declining population. In this sense, one could say that there has been no decline in the service level from a social perspective either.

In addition, the city of Muroran and the town of Iwanai have contracted out their maintenance work to private bodies, or paid local people to maintain infrastructures, in order to reduce public expenditure. Aside from this outsourcing of maintenance, municipalities conduct all maintenance work themselves in order to reduce expenditure. It is evident that involving local people in infrastructure management can reduce public expenditure by municipalities.

Finally, the relationship between industrial structural change and demographic change should also be considered. The three regions surveyed in this study have suffered as a result of industrial decline, such as seeing a decline in fishing resulting from sea desertification, and the reorganisation of governmental sectors, which brought about population decline. As can be seen in the town of Minami Furano, however, demographic change shifts from social change to natural change when the main industry is a primary industry such as agriculture or forestry. This stabilisation of demographic change is better for the regions and their infrastructures. Accordingly, in the municipalities where the main industry is a primary industry, population decline may not have a severe impact on infrastructure.

7.5.3 LOCAL GOVERNMENT FINANCIAL SUPPORT SYSTEM

It is possible that revenue transfer from the central government to municipalities protects municipalities from a more severe impact of population decline on infrastructures in Japan. The municipality revenue level is based on area, population and infrastructure (the revenue transfer system of grant-in-aid from local tax money), as shown in the formula and table below (Figure 76), as introduced in Chapter 4. This support system is prepared for both the prefectural level and the municipality level and some of the indicators and objective measures are different.

This system allows municipality officers to predict future revenue and thus a sustainable level of expenditure. Indeed, financial considerations largely govern the sustainability of infrastructure, as well as the extent of service provision. Furthermore, other factors than the declining population may account for changes to the infrastructure and their effects will be conditioned by internal factors such as the quality of the mayor, the members of the local assembly and the municipality officers, as this study has highlighted.

$$S = uc \times u \times a - (si + 0.75 \times lr + ls)$$

S : standard amount of grant - in - aid from local tax money
uc : unit cost
u : unit
a : adjustment coefficient
si : standard tax income
lt : regional special tax subsidy
ls : local transfer tax

Unit		Unit cost (municipality)
Population		¥22,410 per capita
Area		¥2,562,000/ sq km
....		....
Roads and bridge	Area of roads	¥81,200/thousand sq m
	Length of roads	¥262,000/km
Port	Length of berth	¥30,900/m
	Length of levee	¥6,410/m
Fishery port	Length of berth	¥12,800/m
	Length of levee	¥4,810/m
Urban planning	Population in planned area	¥1,120/m
Park	Population	¥620 per capita
	Area of urban park	¥37.300/thousand sq m
Waste water	Population	¥100 per capita
Other public works	Population	¥1,930 per capita
....		....

Figure 76 Formula for estimating grant-in-aid from local tax money, its unit, S and its unit cost

The transparency of expenditure on infrastructure development and management deserves attention. The revenue transfer system (grant-in-aid derived from local taxation) is based on the level of infrastructure in the municipality concerned, but does not take into consideration the availability of forms of infrastructure. In addition, unit costs for construction, maintenance and salaries have not been confirmed. This means that the mass media, including newspapers and television, and even academic researchers, can readily criticise the lack of transparency regarding expenditure on infrastructure.

This financing support system was originally introduced for balancing the differences of the tax-revenue basis to provide minimum governmental service to the citizens. the tax-revenue ratio between the central and the local authorities is almost 6:4 but the governmental work volume is 4:6. Accordingly, this revenue-transfer system does not directly increase the debt in the central government. Of course, the current debt level of the central government in Japan is enormous, and the financial burden on the future generation is, therefore, increasing. There is, however, no direct link between the tax revenue transfer system and the increase in the future financial burden because the Ministry of Finance can control the unit cost in accordance with the budget situation in the revenue transfer system between the central government and municipalities as discussed in Chapter 4. Consequently, this system can secure the financial resource for infrastructure management not fully, but in certain level.

7.5.4 SUMMARY

In summary, numerous economic, social and geographical forces can be seen to both underpin and mitigate the effects of population decline on infrastructure. These are summarised in Table 32 below. The apparent contradiction of the responses from interviewees is not logical contradiction, but rather suggests the cognitive situation of the municipality officers because impacts such as the closure of infrastructure services, as considered in earlier research, are a natural policy response to prevent or mitigate more serious subsequent situations, and are to be expected by the higher levels of the government and by citizens. This does not always reduce the service level of infrastructure provision because of the strict constraints of geography and the disappearance of the beneficiaries of those infrastructure services. This suggests that the impact will simply not become a problem, and the distinction between the phenomenon and the problem is an important one.

Table 32 Mitigating factors in the impact of population decline on infrastructure management

Item	Mitigating factor
Geographical features	▪ Narrow habitable areas ▪ Proximity to population density areas
Government administrative reform	▪ Controlling investment in accordance with budgetary/economic constraints ▪ Promotion of residential autonomy ▪ Public-private partnerships
Adjustment of infrastructure size	▪ Downsizing capacity of infrastructures during their replacement ▪ Reduction of infrastructure in accordance with social situation
Industry structure	▪ Industry structure mainly composed of primary industries
Local tax system	▪ Revenue transfer system proportional to infrastructure size

7.6 CONCLUDING REMARKS

This chapter discussed the impact of population decline on infrastructure in depopulating municipalities in Japan, based on surveys conducted in those areas. The areas were categorised according to three ranks of population size in order to clarify the actual situation and to obtain information for subsequent quantitative research on this topic.

During the interviews, various phenomena were reported to be caused by population decline; however, none can be regarded as severe due to the strict geographical constraints and the central government's financial support policy for local municipalities, as well as continuous administrative reform.

The importance of distinguishing between a phenomenon and a problem becomes pertinent. In other words, whether the impact of population decline on infrastructure development and management becomes a problem depends on the background situation, such as the geography and policy framework of each country.

In conclusion, we therefore recommend larger scale quantitative survey using a wider sample of municipalities in order to draw more conclusive evidence regarding the impact of population decline on infrastructure so that more objective material can be used to project when and what conditions will result in severe and problematic impacts of population decline on infrastructure development and management.

7.7 ACKNOWLEDGEMENTS

The authors would like to thank Mr Akaishi in Muroran, Mr Oguma and Mr Tezuka in Iwanai, and Mr Takahashi and Ms Yoneki in Minami Furano, for their assistance with this survey.

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CHAPTER 8: ANALYSIS 1: EXPLORING THE LINKS BETWEEN DEPOPULATION AND INFRASTRUCTURE MANAGEMENT IN JAPAN: A BINARY LOGIT REGRESSION ANALYSIS[4]

[4] A part of this chapter has been already published as Uemura, T. and Mourato, S. (2011) Risks of the Impacts on Water Supply and Waste Water Management Infrastructure in Depopulated Regions, Journal of Public Utility Economics, 63(3), 15-28.

8.1 INTRODUCTION

As discussed in Chapter Six, current knowledge of the impact of population decline on infrastructure management is mainly based on case studies and qualitative surveys. In addition, the researchers who conducted previous studies considered the impact on infrastructure in depopulating areas to be the impact of population decline on the infrastructure, but there is still no proof that population decline actually causes the impacts.

Consequently, the following questions should now be investigated quantitatively and comprehensively. First, does population decline actually affect infrastructure management? Second, if population decline affects infrastructure, how does it affect it, i.e. are the impacts different across infrastructure types? Third, which factors other than population decline affect infrastructure management in depopulating areas?

This chapter aims to investigate the relationship between the assumed factors and the impact on infrastructure in depopulating areas, statistically and comprehensively, using an infrastructure sustainability framework, in order to answer the aforementioned research questions. In addition, the study is conducted both from the perspective of infrastructure type and geography, including urban/rural differences, and from the perspective of the extent of population decline.

The structure of the remainder of this chapter is as follows. First, the methodology is introduced in Section 2. In particular, the candidate explanatory variables are described. The analytical results, including the most likely models and resulting independent variables, are presented in Section 3 along with a discussion of their statistical significance. Section 4 concludes the investigation and considers future research tasks.

8.2 METHODOLOGY

8.2.1 RESEARCH STEPS

This study employs a two-step approach. The first step examines whether the impacts of population decline on the various types of infrastructure are the same or not. Although we would expect there to be differences, we have not found literature confirming this expectation. Thus, in the first part of our analysis, we aim to test whether we can indeed observe differential impacts of population decline on different types of infrastructure.

The second step explores in more depth the relationship between the impacts on each of the three major infrastructure types, namely, point type, point-network type and network type, and the decline in population, the factors other than population decline that can relate to these impacts on infrastructure, the differences between infrastructure types, the extent of the change in the probability that an impact will occur in the future according to the trend in population decline, and the types of countermeasures that can be considered.

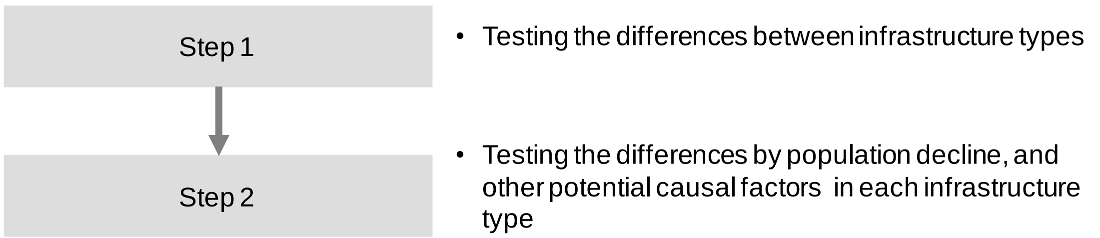

Figure 77 Two-step testing in this study

8.2.2 TYPES OF INFRASTRUCTURE

The types of infrastructure tested are those introduced in the methodology chapter. They were analysed as follows; in step one of this study, the difference in infrastructure category was considered to be the dummy variable in the model. These dummy variables can be used to examine the statistically significant differences in each infrastructure category; some of the impacts are not relevant for some infrastructure types.

In the second step, one of the infrastructure types from each infrastructure category is chosen: public facilities from the point category, water supply and wastewater management from the point–network category, and roads from the network category.

8.2.3 Survey method

The data set for the following analysis was collected from a mail survey undertaken with officers in depopulating municipalities in Japan. Normally in Japan, the questionnaire would be circulated in the responsible department in accordance with the questions when the planning department or public relations department, which deals with requests from the public, received the request. In addition, the directors would also check the responses from practitioners, so that multiple officers are usually involved in this process. This system seemed to work as expected for this project.

The survey enquired about the impact of population decline on infrastructure management, the causes of population decline, the ownership of some types of infrastructure, and the situation of public administrative reforms. It was conducted between August and October 2008. The questionnaire was distributed to 919 municipalities, selected because their populations declined between 1975 and 2000, and the response rate reached almost 50% (Uemura et al. 2008). Experts in the departments of infrastructure management in municipalities responded to the questionnaire.

The questions in the questionnaire are shown in the appendix. The question on impact occurrence refers to the 10 year period ending in 2008, when the survey was conducted. If no answer was given by an expert regarding the impact on infrastructure management, it meant that there was no noticeable impact on the infrastructure. In addition, the data set includes public statistics for the geographic and financial variables that were available on the website of the Government of Japan. The data sources are also shown in Table 35.

8.2.4 Data

8.2.4.1 Dependent variables

To classify and analyse these impacts, a sustainability framework was applied to the study with its four sub-aspects: society, engineering, the environment, and the economy. Each aspect is, of course, multifaceted and very detailed. For example, the engineering aspect includes the number of engineers and technical condition of the infrastructure. The environmental aspect can be divided into three sub-categories: resource use, pollution, and landscape. Many concrete examples can be considered in each of the corresponding four subsets of infrastructure. For the purposes of our analysis, four key types of impacts were chosen as typical, and these were then analysed as the dependent variables of the corresponding aspects in this study: “merging and closing down infrastructure” as a social impact, “decline in maintenance level” as an engineering impact, “resource use” as an environmental impact, and “increase in user charges” as an economic impact.

To answer our key research questions (as detailed in Section 8.2.1.) we employ a two-step approach and conduct two types of analyses. The first analysis pools all infrastructure data and investigates each of the four key types of impact detailed above (i.e. “merging and abolishing facilities” as a social aspect, “decline in maintenance level” as an engineering aspect, “decline in resource use” as an environmental aspect, and “increase in user charge” as an economic aspect) on all seven types of infrastructure (Table 34) simultaneously.

The number of responses per type of infrastructure is introduced in the following results section. In addition, the exact questions asked in the survey are also shown in the tables in the results section.

In turn, the second analysis investigates in more depth a wider range of impacts on each of three selected major infrastructure types separately (for the sake of brevity). Table 33 shows the list of impacts chosen for analysis and the three selected infrastructure types.

Table 33 Selected examples of the impact of population decline on the seven infrastructure types in the first analysis

Type of Infrastructure		Social aspect: Merging and abolishing facilities	Engineering aspect: Decline in maintenance level	Environmental aspect: Decline in resource use	Economic aspect: Increase in user charges
Point	Education	Increase in the number of vacant study rooms, merged and closed facilities owing to the decline in student numbers	Decline in maintenance level (e.g. reducing the frequency of cleaning and snowploughing)	Reduction in electricity and water bills	Increase in user charges, such as school lunch costs
	Public housing	Reduction in the number of houses and flats: the merging and abolition of public dwellings owing to an increase in vacant houses and rooms	Decline in maintenance level (e.g. reducing the frequency of cleaning and snowploughing)	(Not asked, because the use of energy and resources depends on the residents)	Increase in the user burden, such as rents
	Public facilities	Reduction of equipment/mergers and abandonment of facilities	Decline in maintenance level (e.g. reducing the frequency of cleaning and snowploughing)	Reduction in electricity and water bills due to decline in the number of users	Increase in user charges and creation of a user burden system
Point–Network	Water supply and wastewater management	Merging, abolition, and reorganisation of facilities and networks	(Not asked, because the minimum level of water quality is regulated and infrastructure manager has to observed the required regulated standard of quality)	Decrease in the amount of water consumption	Increase in the level of user charges
	Transport	Decline or abolished transport services	Decline in maintenance level (e.g. reducing the frequency of cleaning and snowploughing)	Decline in electricity and water bills for management and operation	Increase in user charges
	Anti-disaster	Abolition of emergency and disaster facilities	Decline in maintenance level (e.g. reducing the frequency of weeding, etc.)	(Not asked, because the workload of anti-disaster facilities does not depend on resource consumption)	(Not asked, because all maintenance costs are financed by the government from tax revenue)
Network	Roads	Abolition of streets in areas where there is no longer a population	Decline in maintenance level (e.g. reducing the frequency of cleaning and snowploughing)	(Not asked, because the workload does not depend on resource consumption)	(Not asked, because the user charge for road development was not levied before 2008)

Table 34 Selected impacts of population decline on the three infrastructure types in the second analysis

Four aspects	Public facilities	Water and wastewater management	Roads
Society	• Decline in the number of users • Merging and closing down facilities	• Merging and closing down facilities	• Decline in traffic
Engineering	• Contracting out operation and maintenance (O&M) work • Decline in the level of maintenance	• Contracting out O&M work	• Decline in the level of maintenance • Contracting out O&M work
Environment	• Energy and resource consumption	• Decline in resource consumption	• Decline in pollution
Economy	• Increase in user charges	• Increase in user charges	• Decline in tax revenue

Note: the selected impacts are not the same across each of the three infrastructure types due to small number of responses in some categories.

8.2.4.2 Explanatory variables

The variables shown in Table 35 were considered to be explanatory variables[5] in the regression analysis in the respective categories. The categories in Table 35 correspond to Equation 8.2. The explanation in Table 35 also shows the meanings of the variables, and the data type shows the character of the data.

This data was selected based on the interview results from the officers of the depopulating municipalities, as in Chapter 7. As discussed in the chapter, geography, the amount of infrastructure, administrative reform and the financial situation are key factors in the extent of the impact of population decline on infrastructure management. In order to analyse the data from many municipalities, its uniformity for explanatory variables is also important. For this, use of statistics with the same definition or the same collection methodology is necessary. In Japan, the Statistics Bureau commonly provides 674 basic data and 46 indicators for municipalities[6]. The following data was selected from the series of data in each category of the common dataset as identified in the previous chapter.

The dummy variables for the seven types of infrastructure, namely education, public housing, public facilities, water supply and wastewater management, transport, roads, and anti-disaster facilities, were first prepared. This was necessary in order to discuss the differences in the occurrence of the impacts across infrastructure types.

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[5] Almost all the correlation values are less than or equal to 0.3 in absolute value, and this means that there are almost no correlations among those variables. Some highly correlated variables are dummy variables for other infrastructure types, but this is natural because municipalities should have infrastructure of the same type, depending on their population sizes. The other slightly problematic correlation is the correlation between the rate of population decline and the ratio of elderly persons to the total population. The correlation value is less than 0.7, and these two variables should also be simultaneously included in this analysis in order to distinguish between the effect of population decline and the effect of ageing. Accordingly, there is no theoretical problem in discussing the selected model and the explanatory variables in the remainder of this thesis.

[6] For prefecture, the Statistics Bureau also provides 4095 basic data and 667 indicators.

The rate of population decline was considered to be one of the important demographic change factors. The rate of population decline was defined by Equation 8.1. As shown in Table 35, six different periods of population decline, looking back five to thirty years in five year intervals from 2005, were considered in the regression models for each impact and infrastructure type.

$$PDR(n) = \frac{P_{2005} - P_{2005-n}}{P_{2005-n}} \quad (8.1)$$

where P_{2005-n} is the population in the year 2005–n; for example, PDR(30) is calculated by comparing the population in 2005 with the population in 1975.

The results calculated by Equation 8.1 have a minus sign, which indicates that the more the population declines; the greater is the number of impacts that occur.

The size of the population was then considered, because the population size of municipalities will dictate the kinds of local government. The percentage of elderly persons relative to the total population was also considered. This number could be regarded as a preceding indicator of population decline. As well as the aforementioned demographic factors, other causes of population decline, such as natural decline, and decline in the main industries in the region, were considered. Causes of population decline should be considered because previous research has observed a small social change in regions whose population has decreased only by natural decline (Uemura et al. 2010). As factors of social decline, we considered “going to higher education or getting jobs”, “closing down branches”, “finishing large public works”, “decline in the main industry”, and “closing down public transport service”. Finally, the way in which population decline occurs, “Dec_pat”, was considered in order to confirm whether the difference in spatial population declining patterns is a key factor.

Third, concerning geographical character, the difference between rural and urban areas was considered by measuring the percentage of the population in densely inhabited districts (DID) compared with the total population of the municipality. The proportion of inhabitable areas compared with the total area of the municipality was considered a geographical constraint. In addition, according to previous interviews, if primary industry becomes the main industry in the region it can sustain the demographic situation. Therefore, the regional character of industry was considered by looking at the number of the population engaged in the primary industry in the national census in 2005. Note that the mining sector is not included among the primary industries in Japan.

Fourth, with respect to the amount of infrastructure, the official statistics for education facilities, libraries and community facilities, urban parks, wastewater facilities, and the length of roads were converted to percentages for the area. Binary scores for public housing, transport, and anti-disaster facilities were given according to whether or not the facilities were owned by the municipality, owing to data constraints.

Fifth, with regard to administrative reforms in municipalities, “reorganising public service provision for residents”, “merging and closing down public facilities”, “increasing or introducing contracting out”, “downsizing the financial size of municipalities”, “reviewing the salary levels of public officers”, “introducing e-government to municipalities”, and “not enough administrative reforms conducted” were considered to be variables, and the data for these came from the mail survey results for the depopulating municipalities in Japan.

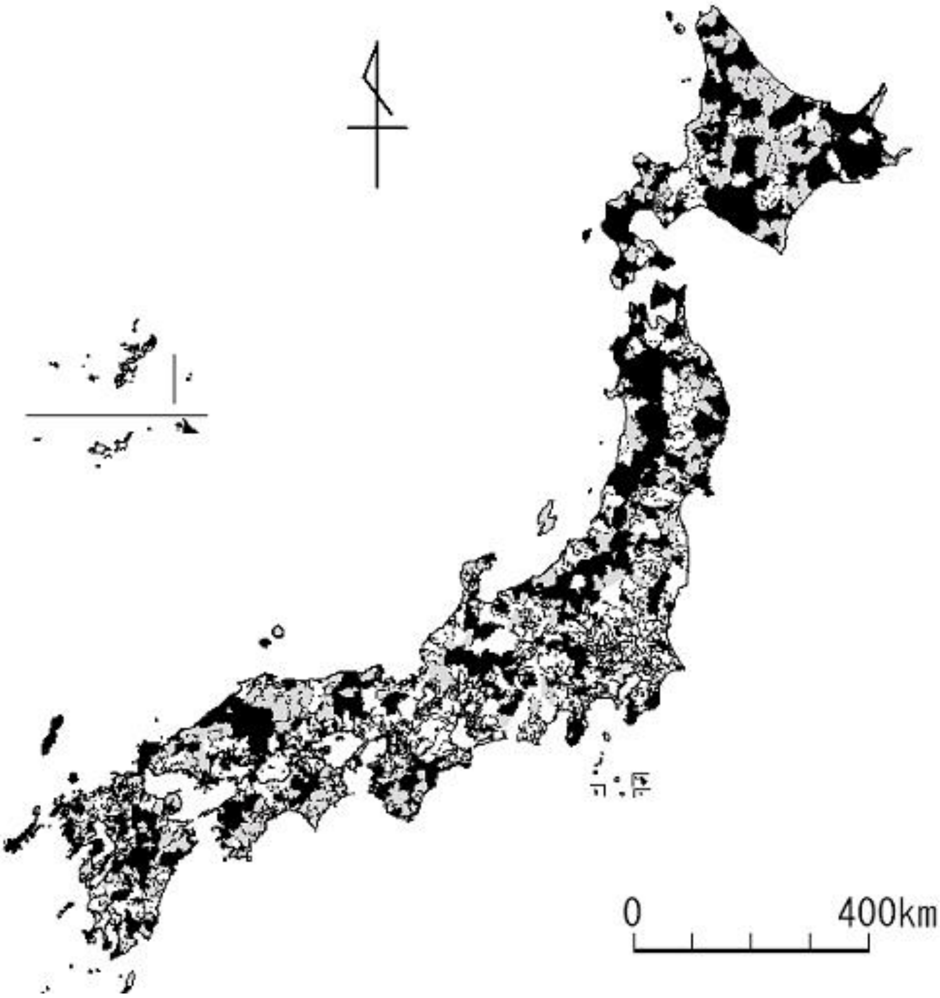
Finally, as regards the variables of the financial situation, revenue-expenditure balance and debt-repayment outlay, both as a percentage of the total budget size, were also considered. It was assumed that the former represented financial health and the latter represented the degree of financial flexibility for the municipality.

Table 35 Explanatory variables

Category	Variables	Explanation	Average	Median	Standard deviation	No of "Yes"	Ratio of response	Data type	Data source
Dummy of infrastructure type	D_edu	Dummy variable of education						Binary (0/1)	
	D_ph	Dummy variable of public housing						Binary (0/1)	
	D_ls	Dummy variable of life-related facilities (public facilities)						Binary (0/1)	
	D_ww	Dummy variable of water supply and waste water management						Binary (0/1)	
	D_trans	Dummy variable of public transport						Binary (0/1)	
	D_road	Dummy variable of road						Binary (0/1)	
	D_disas	Dummy variable of anti-disaster facilities						Binary (0/1)	
Demographic change	PDR30	Rate of population decline between 1975 and 2005	-0.21	-0.19	0.12			Percentage	National Census of Japan
	PDR25	Rate of population decline between 1980 and 2005	-0.19	-0.18	0.10			Percentage	National Census of Japan
	PDR20	Rate of population decline between 1985 and 2005	-0.17	-0.16	0.09			Percentage	National Census of Japan
	PDR15	Rate of population decline between 1990 and 2005	-0.13	-0.12	0.07			Percentage	National Census of Japan
	PDR10	Rate of population decline between 1995 and 2005	-0.09	-0.09	0.05			Percentage	National Census of Japan
	PDR5	Rate of population decline between 2000 and 2005	-0.05	-0.05	0.03			Percentage	National Census of Japan
	PopSize	Population in 2005 (thousands)	31.70	12.30	61.71			Numeric	National Census of Japan
	Elderly	Rate of population over 65 years old to total population in 2005	0.30	0.29	0.06			Percentage	National Census of Japan
	ND	Cause of population decline: natural decline (yes=1/no=0)	0.98	1.00	0.14	448	98.0%	Binary (0/1)	Nomura Research Institute (2008)
	SD_ER	Cause of population decline: higher education or recruiting (yes=1/no=0)	0.88	1.00	0.32	404	88.4%	Binary (0/1)	Nomura Research Institute (2008)
	SD_AB	Cause of population decline: abolishing branches (yes=1/no=0)	0.12	0.00	0.32	53	11.6%	Binary (0/1)	Nomura Research Institute (2008)
	SD_AT	Cause of population decline: abolishing public transports (yes=1/no=0)	0.04	0.00	0.19	17	3.7%	Binary (0/1)	Nomura Research Institute (2008)
	SD_FC	Cause of population decline: finishing large public works(yes=1/no=0)	0.04	0.00	0.20	19	4.2%	Binary (0/1)	Nomura Research Institute (2008)
	SD_DI	Cause of population decline: main industry decline(yes=1/no=0)	0.37	0.00	0.48	167	36.5%	Binary (0/1)	Nomura Research Institute (2008)
	Dec_Pat	How population decline happens (1=partial/0=holistic)	0.22	0.00	0.42	101	22.2%	Binary (0/1)	Nomura Research Institute (2008)
Geographic factors	Area	Areas of municipalities (km^2)	287.06	204.77	262.59			Numeric	Suji de miru Shi Ku Chou Son [public statistics] (2008)
	DIDPop	Ratio of population in the densely inhabited district to total population in 2005 (indicator of urban/rural)	0.11	0.00	0.23			Percentage	Suji de miru Shi Ku Chou Son [public statistics] (2008)
	HabitableA	Ratio of habitable areas in the areas of municipality in 2006（Indicators of hardness of geography)	0.32	0.25	0.22			Percentage	Suji de miru Shi Ku Chou Son [public statistics] (2008)
	PrimeIndustry	Ration of population in primary industry to population between 15 years and 65 years old	0.18	0.17	0.11			Percentage	Suji de miru Shi Ku Chou Son [public statistics] (2008)
Amount of infrastructure	Schools	Number of schools per unit area in 2005	0.23	0.09	0.74			Percentage	Suji de miru Shi Ku Chou Son [public statistics] (2008)
	Housing	Ownership of public dwellings in 2008 (Yes=1/ no=0)	0.98	1.00	0.12	451	98.5%	Binary (0/1)	Nomura Research Institute (2008)
	Facilities	Number of libraries and community houses per unit area in 2005	0.06	0.03	0.10			Percentage	Suji de miru Shi Ku Chou Son [public statistics] (2008)
	Parks	Number of parks per unit area in 2005	0.16	0.01	0.81			Percentage	Suji de miru Shi Ku Chou Son [public statistics] (2008)
	Tanks	Number of septic tanks per unit area in 2004	0.05	0.02	0.10			Percentage	Suji de miru Shi Ku Chou Son [public statistics] (2008)
	Transport	Existence of public transport facilities in 2008 (Yes=1/no=0)	0.28	0.00	0.45	127	27.7%	Binary (0/1)	Nomura Research Institute (2008)
	Road	Road length per unit area in 2005 (km/km2)	2.41	1.55	2.87			Percentage	Suji de miru Shi Ku Chou Son [public statistics] (2008)
	A-Disaster	Existing of anti-disaster facilities in 2008 (Yes=1/no=0)	0.41	0.00	0.49	187	40.8%	Binary (0/1)	Nomura Research Institute (2008)
Public administration	re_P.Service	Reform of public administration services in 2008 (Yes=1/no=0)	0.76	1.00	0.43	346	75.5%	Binary (0/1)	Nomura Research Institute (2008)
	M&A_Facilities	Abolishing public facilities or infrastructure in 2008 (Yes=1/no=0)	0.66	1.00	0.48	300	65.5%	Binary (0/1)	Nomura Research Institute (2008)
	Contrac-out	Promoting contracting out in 2008 (Yes=1/no=0)	0.86	1.00	0.35	394	86.0%	Binary (0/1)	Nomura Research Institute (2008)
	Downsize_Finance	Downsizing budget in 2008 (Yes=1/no=0)	0.51	1.00	0.50	234	51.1%	Binary (0/1)	Nomura Research Institute (2008)
	Re_Salary	Reforms of salary system of municipality officers in 2008 (Yes=1/no=0)	0.96	1.00	0.19	440	96.1%	Binary (0/1)	Nomura Research Institute (2008)
	e-Gov	Promoting e-government in 2008 (Yes=1/no=0)	0.24	0.00	0.43	112	24.5%	Binary (0/1)	Nomura Research Institute (2008)
	Not_Enough	Insufficient public administration reform in 2008 (Yes=1/no=0)	0.01	0.00	0.09	4	0.9%	Binary (0/1)	Nomura Research Institute (2008)
Financial situation	Reve-Expend	Ratio of general revenue and expenditure balance in 2005	0.04	0.04	0.04			Percentage	Suji de miru Shi Ku Chou Son [public statistics] (2008)
	Debt-Repay	Ratio of debt repayment in 2005	0.16	0.16	0.05			Percentage	Suji de miru Shi Ku Chou Son [public statistics] (2008)

8.2.5 *Sample collection*

As a result of the mail survey, 464 responses were collected from depopulating municipalities. Figure 78 shows the distribution of the responses to the mail survey (Nomura Research Institute 2008). The data was obtained from all over Japan. The response rate was almost 50% in each category by municipality population size: fewer than 10,000; more than or equal to 10,000; fewer than 50,000; and more than or equal to 100,000. The results for the municipalities that responded, for example, for population decline rates, areas, situation of public administrative reforms, and financial situation, are introduced in the section on explanatory variables.



Note: Black shows the municipalities that responded to the survey. Grey shows the municipalities to which surveys were distributed but which did not respond. White shows municipalities to which surveys were not distributed.
Source: Nomura Research Institute (2008)

Figure 78 Response situation for the survey of municipal officers

The survey was prepared for seven types of infrastructure: public facilities, education, public housing, water supply and wastewater management facilities (water and wastewater as shown in Table 36), transport, anti-disaster (as shown in Table 36), and roads. Not all sampled municipalities have all the infrastructure types, so the number of responses for each type of infrastructure varied from 464 (100% of responses) to 129 (27.8% of responses).

Table 36 Number of samples in each infrastructure type

Types of infrastructure		Number of samples (responses)	%
Point type	Public facilities	459	98.9%
	Education	464	100.0%
	Public housing	457	98.5%
Point-network	Water and waste water	464	100.0%
	Transport	129	27.8%
	Disaster	187	40.3%
Network	Road	464	100.0%

8.2.6 MODEL

8.2.6.1 Binary logit regression analysis

The impacts on infrastructure management in depopulating municipalities, which are dependent variables in the models, were collected from the relevant officers in these municipalities as binary-type data in the mail survey. When a dependent variable produces discrete data, either a probit model or a logit model (logistic regression model) is generally used for analysis. Alternatively, derivatives considering random effects or fixed effects for the panel data are used. The data in this case is not panel data; therefore, either a simple probit model or a logit model can be applied.

As is well known, the difference between logit and probit models is the assumption of either a normal distribution or a logistic distribution for the error distribution. The difference between the models is not very significant when the response rate of the dependent variables is approximately 50%. However, when the response rate is either extremely small or very large, which is the case observed in this data set, it is recognised that the logit model tends to produce larger estimation results than those of the probit model. There is, however, no definitive conclusion: there are many arguments about which model are superior (Greene 2003). In this case, the logit model was applied to the data for ease of estimation.

Potential variables for the regression analysis were selected according to the results of the literature review (Uemura and Mourato 2012) and previous interviews on this issue (Uemura et al. 2010). As a result of the literature review, demographic characteristics, such as the differences between urban and rural areas and the difference in the speed of population decline, could be considered factors relating to the impact of population decline on infrastructure management. It is also thought that types of infrastructure can affect the extent or occurrence of the impact (Uemura and Mourato 2012), and these are also regarded as control variables between municipalities. From the results of the interviews on depopulating municipalities in Japan, it was strongly expected that geographical character, governmental reform, the amount of infrastructure, industrial structures, and the financial situations of the public finance institutions would all be candidates for investigation (Uemura et al. 2010).

Accordingly, these six categories of demographic factors, geographical factors (including both the differences between urban and rural areas and geographical aspects such as whether areas are mountainous or flat), the amount of infrastructure, public administrative reforms, the financial situations of municipalities, and the types of infrastructure, were selected as explanatory variable categories, as can be seen in Table 35.

As noted above when developing the models, this study takes a two-step approach to investigating our key research questions (see Section 8.2.1). The first model focuses on the first research question, in other words, on directly confirming the differences between impacts on infrastructure types. As mentioned in the literature review, there is little previous research on the relationship between population decline and its impact on infrastructure development and management. Before moving to a detailed discussion, we should therefore make sure of the basic facts. Equation 8.2 is used for this purpose. The details and concrete definitions of the variables will be introduced in Table 35, but Equation 8.2 was applied for each period of population decline from 5 years (t=5) to 30 years (t=30) with a benchmarked year of 2005.

Logit(impact)=D_edu+D_ph+D_lf+D_ww+D_trans+D_road+D_disas+PDR(t)+PopSize1000persons+Elderly+ND+SD_ER+SD_AB+SD_AT+SD_FC+SD_DI+Dec_Pat+Areakm2+DIDPop+HabitableA+PrimeIndustry+Schools+Housing+Facilities+Parks+Tanks+Transport+Road+ADisaster+re_P.Service+MA_Facilities+Contracout+Downsize_Finance+Re_Salary+eGov+Not_Enough+ReveExpend+DebtRepay

(8.2)

where "impact" = 1 when the impact occurred for one example of the infrastructure of the seven types.

In the second step, Equation 8.2 was modified to form Equation 8.3 in order to conduct a similar analysis for each infrastructure type as follows:

Logit(impact)=PDR(t)+PopSize1000persons+Elderly+ND+SD_ER+SD_AB+SD_AT+SD_FC+SD_DI+Dec_Pat+Areakm2+DIDPop+HabitableA+PrimeIndustry+Schools+Housing+Facilities+Parks+Tanks+Transport+Road+ADisaster+re_P.Service+MA_Facilities+Contracout+Downsize_Finance+Re_Salary+eGov+Not_Enough+ReveExpend+DebtRepay

(8.3)

where "impact" = 1 when the impact occurred for the specific infrastructure tested.

Equation 8.3 is applied for each period of population decline from 5 years (t=5) to 30 years (t=30) as well as to the three types of infrastructure: "public facilities" as a point type of infrastructure, "water and wastewater management" as a point–network type of infrastructure, and "roads" as a network type of infrastructure.

In the process of estimation using "SPSS 16.0" or "R", either the backward-stepwise method with Wald statistics, or the forward stepwise method with AIC (Akaike Information Criteria) to select significant variables, was used in order to identify the most relevant model in each period of population decline. In other words, in the first step, all variables in Table 35 were entered into the binary logit regression model simultaneously. Afterwards, the variables with insignificant Wald statistics were removed from the updated model. At this stage, the stepwise method cannot automatically remove those variables that are highly correlated. Therefore, after the regression, if insignificant explanatory variables remained in the model, they were removed by hand and the model was estimated again, so that the re-estimated model was regarded as the final model. If more than two models were identified as significant, the model with the smallest AIC was regarded as the best model for the impact.

The Nagelkerke R square (Nagelkerke 1991) could be used as the indicator for the appraisal of the fitness of the model. This Nagelkerke R square is similar to the adjusted coefficient of determination for a multiple linear regression model, and thus it is often used for assessment of the fitness of the binary logistic regression model.

$$\bar{R}^2_{\text{Nagelkerke}} = \frac{1 - \left\{ \frac{L(0)}{L(\hat{\beta})} \right\}^{\frac{2}{n}}}{1 - \{L(0)\}^{\frac{2}{n}}} \tag{8.4}$$

When the "R" statistics software is used for the estimation of binary logistic regression models and for testing the fitness of the models, "lrm" in the "Design" package and "glm" in the "Stats" package are used. Both can estimate binary logistic models, but they produce different statistical outputs. The "lrm" can produce the results of the likelihood ratio test and Nagelkerke R square, while the "glm" can calculate the AIC. This time, the two programmes were applied and the results were cross-checked before the statistics were used. The actual programme for estimation is described in the appendix.

8.2.6.2 Risk analysis

Equation 8.5 is calculated in order to show the net impact of population decline on infrastructure management:

$$\Pr_i = \frac{\exp(\beta_i * PDR(n) + C_i)}{1 + \exp(\beta_i * PDR(n) + C_i)} \tag{8.5}$$

where $\Pr_i$ is the probability of the occurrence of the impact on the infrastructure, β_i is the coefficient of PDR(n) for the impact type, and C_i is the estimated constant in each regression result. All are calculated for a particular impact i.

8.2.6.3 Sustainability analysis

In order to assess the sustainability of the infrastructure, the balance between the four aspects and the chronological change in that balance should be discussed. In particular, the interest of this study lies in the relationship between population decline and the impact on infrastructure management. For this purpose, this study introduces the following two-step approach.

First, the impact of population change between 2005 and 2010 is checked. For this, the rate of population decline between 2000 and 2005 is converted into the rate of population decline between 2005 and 2010 in the models identified in this study and the change in the impact occurrence in the four aspects is discussed using the city of Hakodate between 2005 and 2010 as an example.

The second step represents the way a policymaker might manage that change. This study considers the “amount of infrastructure”, “governmental administrative reforms”, and “financial situation” in municipalities as policy variables. It also evaluates the change by controlling for these variables in the model. Once this study assumes that one of the governmental administrative reforms, which are significant variables, that has not been carried out by the city of Hakodate will be carried out, the effect of such policy countermeasure can also be confirmed.

8.3 RESULTS

8.3.1 DESCRIPTIVE STATISTICS OF DEPENDENT VARIABLES

The wide range of impacts given in the survey, including the impacts used as dependent variables in the two models, is introduced in the following sections.

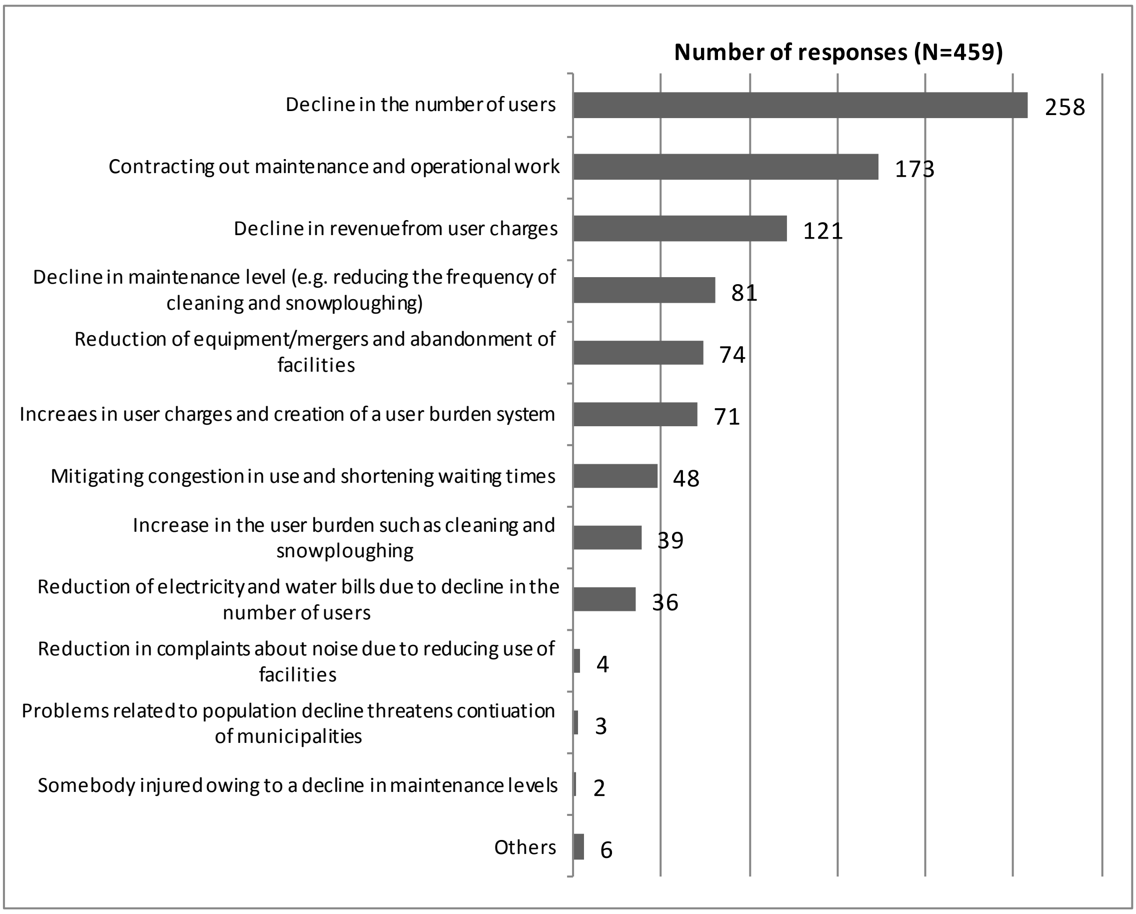
8.3.1.1 Public facilities

Simple descriptive results from the structured mail survey on public facilities are shown in Figure 79. The highest response for social aspects was for “Decline in the number of users”, with more than 50% of municipalities facing this impact in depopulating areas, while the response rate for “Reducing equipment, or merger and closure of facilities” was only one third of that. This finding suggests that some thresholds can be expected to exist when the spatial service level of public facilities is changed.

From the engineering perspective, “Contracting out maintenance and operational work” is also a major impact according to the survey. More than one third of municipalities have experienced this impact, and 17.6% of municipalities have also experienced a decline in maintenance levels. In this way, engineering impacts apparently result in a serious situation in the municipality, but injuries resulting from these impacts are rare. Accordingly, it can be concluded that there will usually be an engineering impact, but that serious situations are unlikely to occur.

Environmental impacts such as “Reduction in electricity and water bills due to a decline in the number of users” and “Reduction in complaints about noise due to reduced use of facilities” are not particularly serious according to the survey results. Public facilities need energy and water regardless of the number of users, and public facilities may not have originally made any noise while providing their services to the public.

Finally, the decline in revenue from user charges, an economic aspect, was reported as the third highest response in the survey. In some cases, there is no charge when the public uses public facilities. However, in order to cope with the financial constraints due to the decline in the number of users, municipalities can introduce a user charging system. In fact, few municipalities have introduced such a financial solution to manage their public facilities. In conclusion, engineering and economic impacts are often reported, but they are not currently very serious.



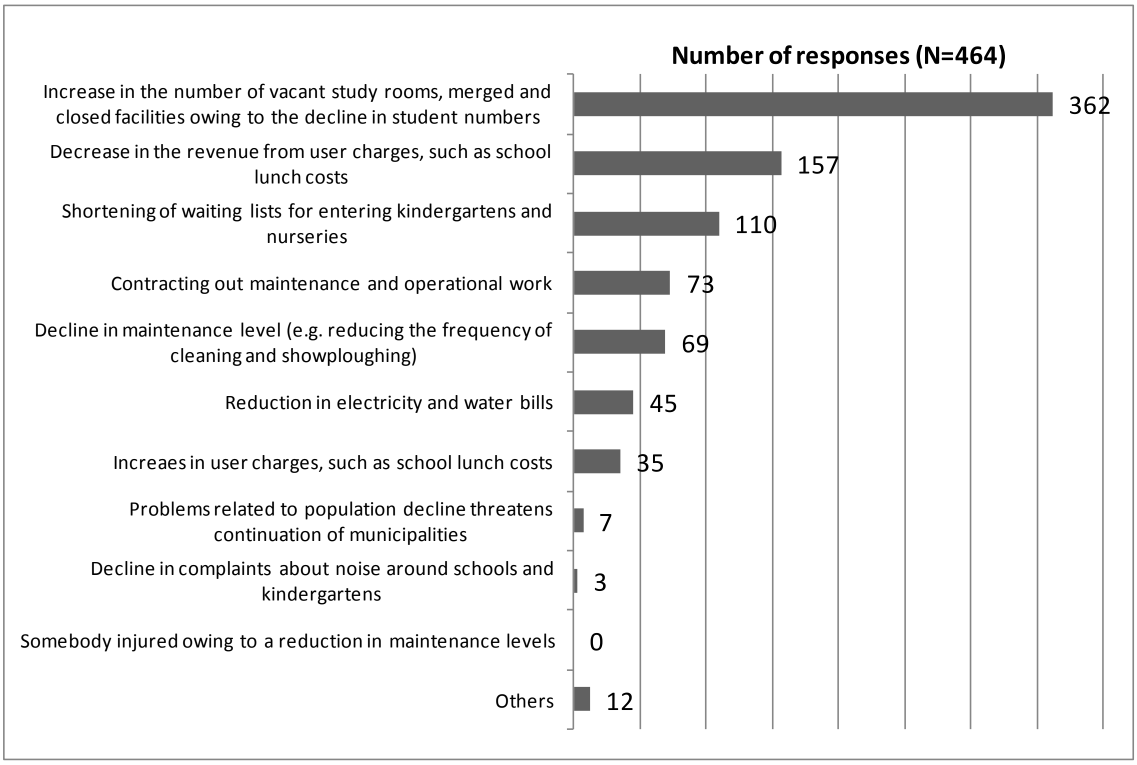
Questions for Public facilities	No. of responses	%
Decline in the number of users	258	56.2%
Contracting out maintenance and operational work	173	37.7%
Decline in revenuefrom user charges	121	26.4%
Decline in maintenance level (e.g. reducing the frequency of cleaning and snowploughing)	81	17.6%
Reduction of equipment/mergers and abandonment of facilities	74	16.1%
Increaes in user charges and creation of a user burden system	71	15.5%
Mitigating congestion in use and shortening waiting times	48	10.5%
Increase in the user burden such as cleaning and snowploughing	39	8.5%
Reduction of electricity and water bills due to decline in the number of users	36	7.8%
Reduction in complaints about noise due to reducing use of facilities	4	0.9%
Problems related to population decline threatens contiuation of municipalities	3	0.7%
Somebody injured owing to a decline in maintenance levels	2	0.4%
Others	6	1.3%

Figure 79 Simple results of the impact of population decline on public facilities

8.3.1.2 Education

Descriptive results from the structured mail survey on education are shown in Figure 80. In the education sector, “Increase in the number of vacant study rooms, merged and closed facilities owing to the decline in student numbers”, in the social aspect, has the largest number of responses, and almost 80% of municipalities have experienced this. At the same time, the economic impact of “Decrease in revenue from user charges, such as school lunch costs” has a large number of responses, in contrast to only a limited number of responses for “Increase in user charges, such as school lunch costs”. This suggests that municipalities try to deal with the serious economic situations in the education sector in order to keep and increase the young population.

Engineering aspects such as “Contracting out maintenance and operational work” and “Decline in maintenance level (e.g. reducing the frequency of cleaning and snowploughing)” are the fourth and fifth largest impacts, but were only experienced by around 15% of municipalities. The environmental impact, in this case, is in fact positive. “Reduction in electricity and water bills” is reported by less than 10% of municipalities, and this is therefore not a major impact due to population decline in the education sector. In conclusion, social and economic impacts are the most severe in the education sector, but municipalities bear the financial difficulties in the education sector in order to sustain and increase the younger generation.



Questions for Education	No. of responses	%
Increase in the number of vacant study rooms, merged and closed facilities owing to the decline in student numbers	362	78.0%
Decrease in the revenue from user charges, such as school lunch costs	157	33.8%
Shortening of waiting lists for entering kindergartens and nurseries	110	23.7%
Contracting out maintenance and operational work	73	15.7%
Decline in maintenance level (e.g. reducing the frequency of cleaning and showploughing)	69	14.9%
Reduction in electricity and water bills	45	9.7%
Increaes in user charges, such as school lunch costs	35	7.5%
Problems related to population decline threatens continuation of municipalities	7	1.5%
Decline in complaints about noise around schools and kindergartens	3	0.6%
Somebody injured owing to a reduction in maintenance levels	0	0.0%
Others	12	2.6%

Figure 80 Simple results of the impact of population decline on education facilities

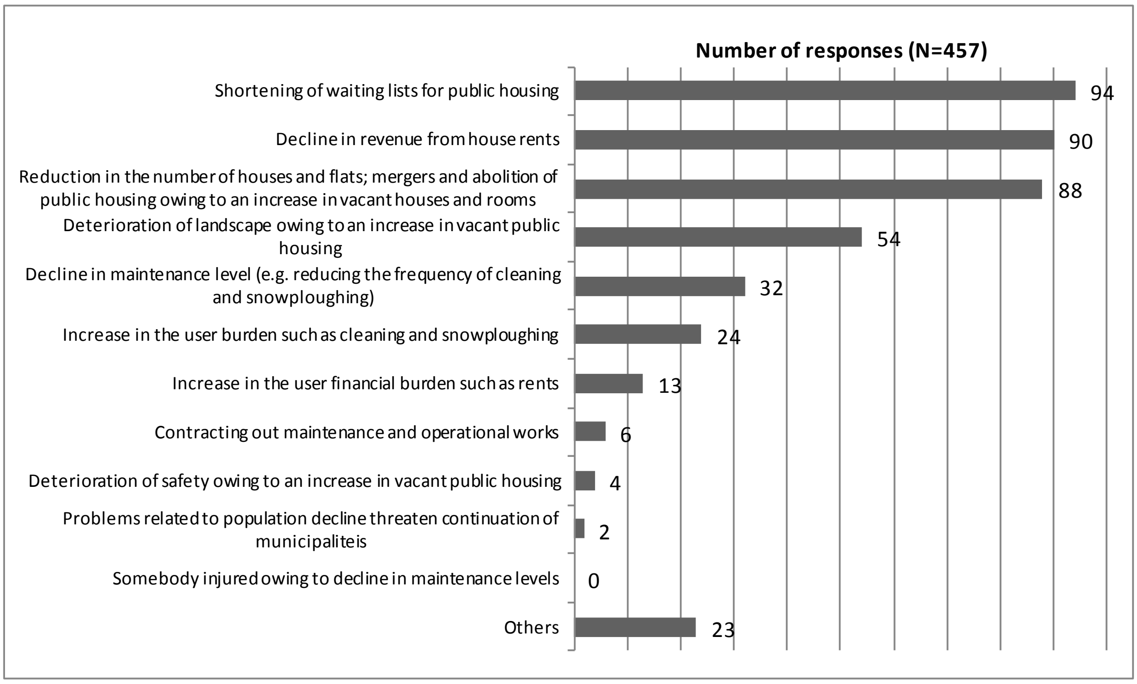
8.3.1.3 Public housing

Descriptive results from the structured mail survey on public housing are shown in Figure 81; the number of responses is smaller than for all other infrastructure sectors except for roads and anti-disaster facilities. It is noted that the vacancy rate of public housing was not surveyed in this questionnaire, because the municipality controls the vacancy rate of public housing from a policy perspective, so that it does not directly reflect the population decline. The purpose of the policy includes supporting poor households, the elderly, and people who have suffered from disasters. Alternatively, some municipalities intentionally stop recruiting new residents to demolish or rebuild public housing. These policy activities were found in the interviews about depopulating municipalities. Accordingly, it was considered that an increase or decrease of vacancies in public housing cannot be identified as an impact of population decline.

In the social aspect, although there has been a “Shortening of waiting lists for public dwellings”, there has been a simultaneous reduction in the quantity of public housing, according to the response to “Reduction in the number of houses and flats; mergers and sales of public dwellings owing to an increase in vacant houses and rooms”. This finding suggests that the number of households needing public housing is declining rapidly due to population decline.

Economic impacts such as “Decline in the revenue from house rents” is the second highest response in the survey, while the negative impacts of “Increase in the user burden, such as cleaning and snowploughing” and “Increase in the user burden, such as rents” are rarely mentioned. This may be because public housing residents cannot be both rich and old; therefore, they cannot bear such increases in costs. Accordingly, this deficit will be covered by other people in municipalities.

Against this situation, municipalities did not employ policies such as “Decline in maintenance level (e.g. reducing the frequency of cleaning and snowploughing)” or “Contracting out maintenance and operational work” in the engineering aspect. The original level of maintenance work may not have been high, so there would have been little scope to reduce the level of maintenance.



Questions for Public housing	No. of responses	%
Shortening of waiting lists for public housing	94	20.6%
Decline in revenue from house rents	90	19.7%
Reduction in the number of houses and flats; mergers and abolition of public housing owing to an increase in vacant houses and rooms	88	19.3%
Deterioration of landscape owing to an increase in vacant public housing	54	11.8%
Decline in maintenance level (e.g. reducing the frequency of cleaning and snowploughing)	32	7.0%
Increase in the user burden such as cleaning and snowploughing	24	5.3%
Increase in the user financial burden such as rents	13	2.8%
Contracting out maintenance and operational works	6	1.3%
Deterioration of safety owing to an increase in vacant public housing	4	0.9%
Problems related to population decline threaten continuation of municipaliteis	2	0.4%
Somebody injured owing to decline in maintenance levels	0	0.0%
Others	23	5.0%

Figure 81 Simple results of the impact of population decline on public housing

By contrast, an environmental impact such as “Deterioration of landscape owing to an increase in vacant public dwellings” is the fourth largest response. This is because old public housing consists, in many cases, of terraced houses; if only one household lives in terraced public housing, using a couple of rooms, municipalities cannot demolish the house. They can only board up the doors and windows of vacant rooms with plywood and wait until the last family moves out of their own volition.

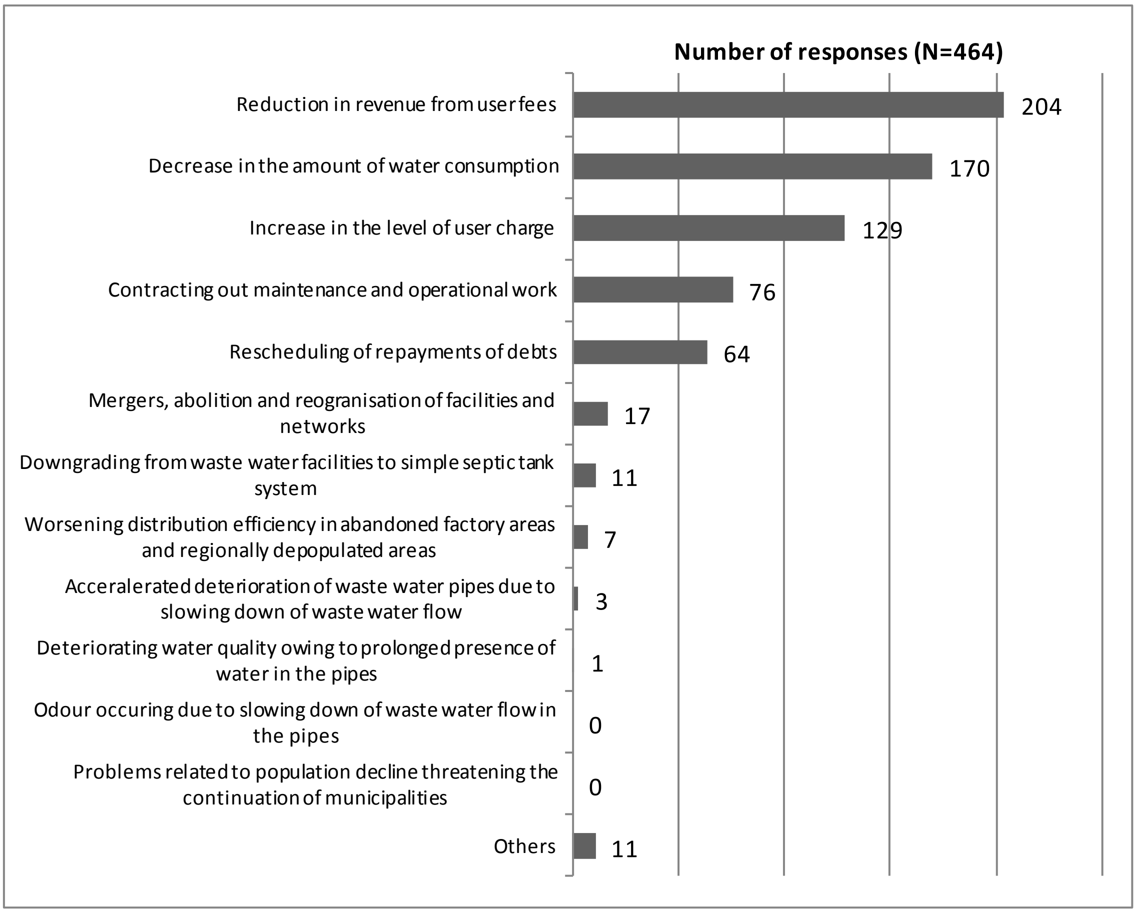
In this way, except for some municipalities that are able to demolish their public housing, most municipalities have to care for their public housing for as long as residents continue to live there. The difficulty is that the population in public housing, who are either poor or old, is invaluable in an area facing population decline. Policy on the development and management of public housing in depopulating areas is thus a delicate matter.

8.3.1.4 Water and wastewater management

Descriptive results from the structured mail survey on water and wastewater management are shown in Figure 82. In this sector, economic aspects seem to be the most serious according to respondents. "The reduction of revenue from user fees" has the top score out of all impacts on the list. To cope with this decline, 27.8% of depopulating municipalities have increased the user charge.

By contrast, declines in the number of users and in water consumption, as expected, contribute to improving the environmental situation. Contrary to the German case (Moss 2003), the negative impacts of "Deteriorating water quality owing to the prolonged presence of water in the pipes" and "Odour occurring due to the slowing down of wastewater flow in the pipes" may not happen. As a result, depopulating Japanese municipalities can enjoy these positive environmental impacts of population decline.

Engineering impacts such as "Contracting out maintenance and operational work" are also linked to the financial situation, but as opposed to the responses in the economic aspect, only 16.4% of depopulating municipalities have outsourced operations and maintenance work. In this sector, by contrast, social impacts such as "Mergers, closures and the reorganisation of facilities and networks" have rarely happened. The main impact in this sector is thus economic, but Japanese depopulating municipalities do not face a serious situation, in contrast to German municipalities.



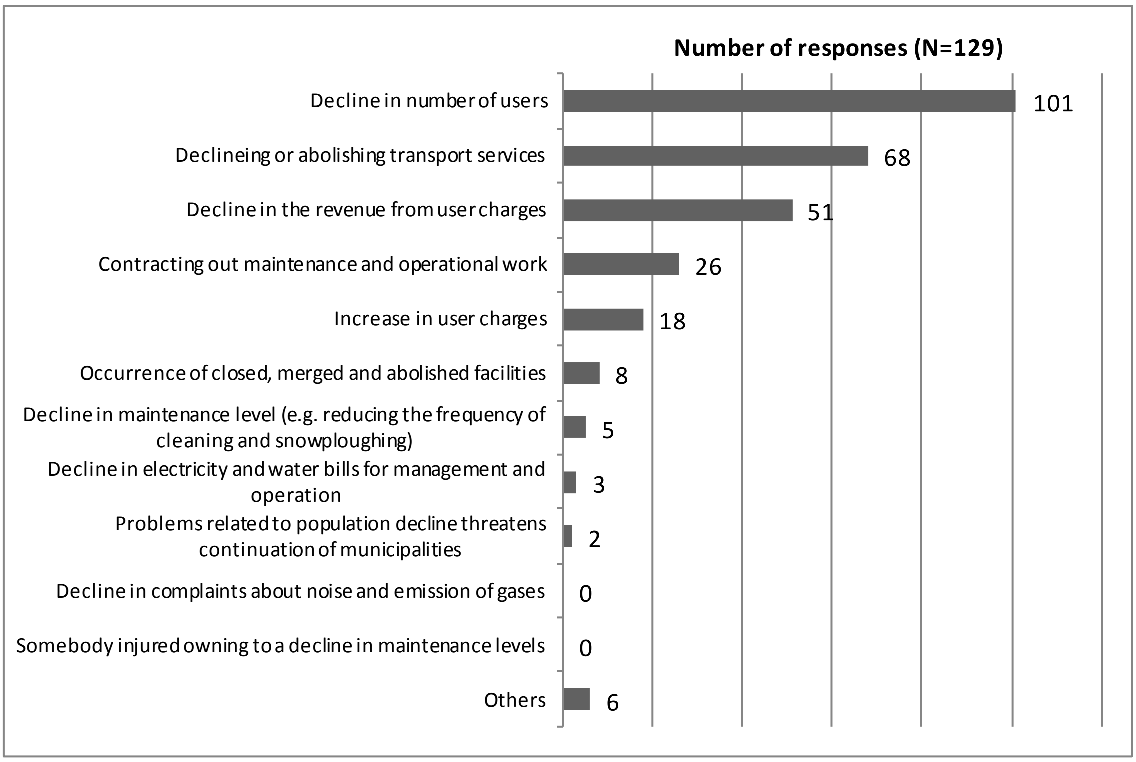
Questions for Water supply and waste water management	No. of responses	%
Reduction in revenue from user fees	204	44.0%
Decrease in the amount of water consumption	170	36.6%
Increase in the level of user charge	129	27.8%
Contracting out maintenance and operational work	76	16.4%
Rescheduling of repayments of debts	64	13.8%
Mergers, abolition and reogranisation of facilities and networks	17	3.7%
Downgrading from waste water facilities to simple septic tank system	11	2.4%
Worsening distribution efficiency in abandoned factory areas and regionally depopulated areas	7	1.5%
Acceralerated deterioration of waste water pipes due to slowing down of waste water flow	3	0.6%
Deteriorating water quality owing to prolonged presence of water in the pipes	1	0.2%
Odour occuring due to slowing down of waste water flow in the pipes	0	0.0%
Problems related to population decline threatening the continuation of municipalities	0	0.0%
Others	11	2.4%

Figure 82 Simple results of the impact of population decline on water and wastewater management

8.3.1.5 Transport

Descriptive results from the structured mail survey about transport are shown in Figure 83. Originally, only 129 municipalities had a transport infrastructure, but almost 80% faced a decline in the number of users. To cope with this situation, more than half municipalities have suspended their public transport services – a social impact. Naturally, they also face a decline in revenue from public transport services, but not all of them can raise their tariffs for transport services.

Contracting out O&M work, an engineering impact, can also contribute towards reducing municipality costs of operating public transport, but only 20.2% of municipalities have introduced this policy. Most municipalities have therefore faced difficulties in continuing to provide their public transport services, but been unable to find good solutions.

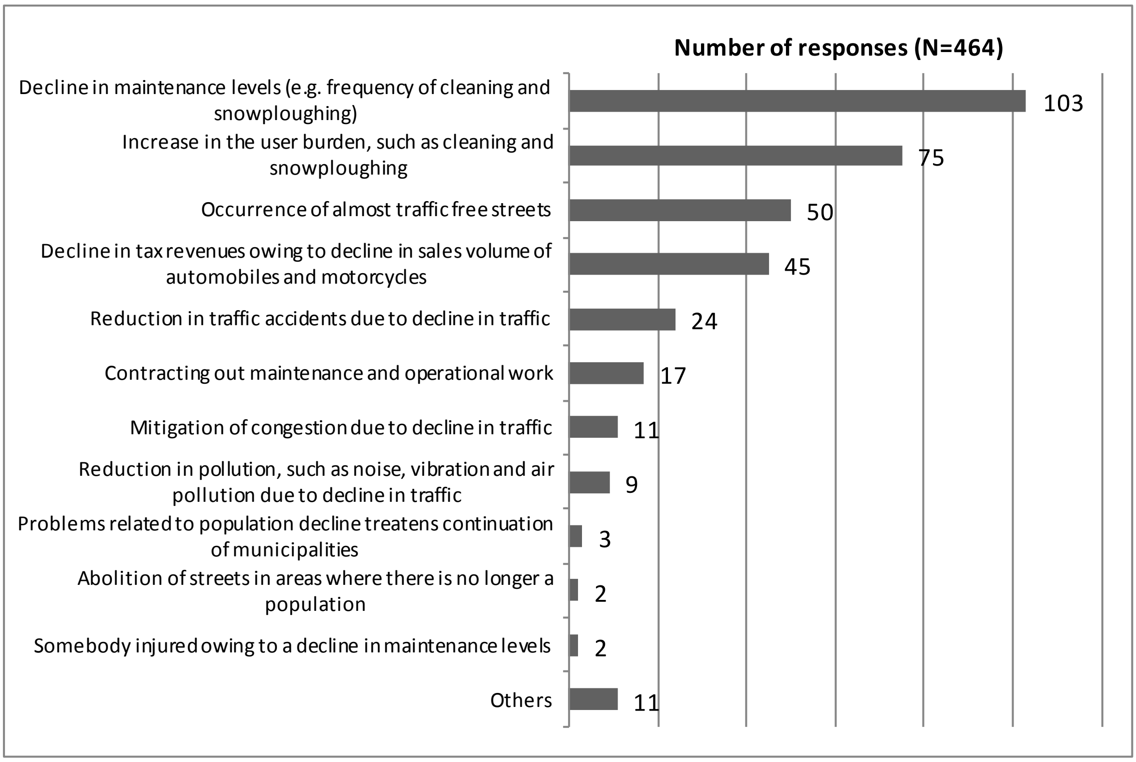


Questions for Transport	No. of responses	%
Decline in number of users	101	78.3%
Declineing or abolishing transport services	68	52.7%
Decline in the revenue from user charges	51	39.5%
Contracting out maintenance and operational work	26	20.2%
Increase in user charges	18	14.0%
Occurrence of closed, merged and abolished facilities	8	6.2%
Decline in maintenance level (e.g. reducing the frequency of cleaning and snowploughing)	5	3.9%
Decline in electricity and water bills for management and operation	3	2.3%
Problems related to population decline threatens continuation of municipalities	2	1.6%
Decline in complaints about noise and emission of gases	0	0.0%
Somebody injured owning to a decline in maintenance levels	0	0.0%
Others	6	4.7%

Figure 83 Simple results of the impact of population decline on transport

8.3.1.6 Roads

Descriptive results from the structured mail survey about roads are shown in Figure 84. Engineering responses to the situation are the most common solution, but only 22.2% of depopulating municipalities have introduced such policies. To cope with this situation, municipalities have also asked residents to cooperate and conduct road maintenance work, as an economic impact where there is declining tax revenue, although the decision to contract out the O&M of roads is rarely taken. Impacts other than environmental and social aspects are not common in the roads sector.

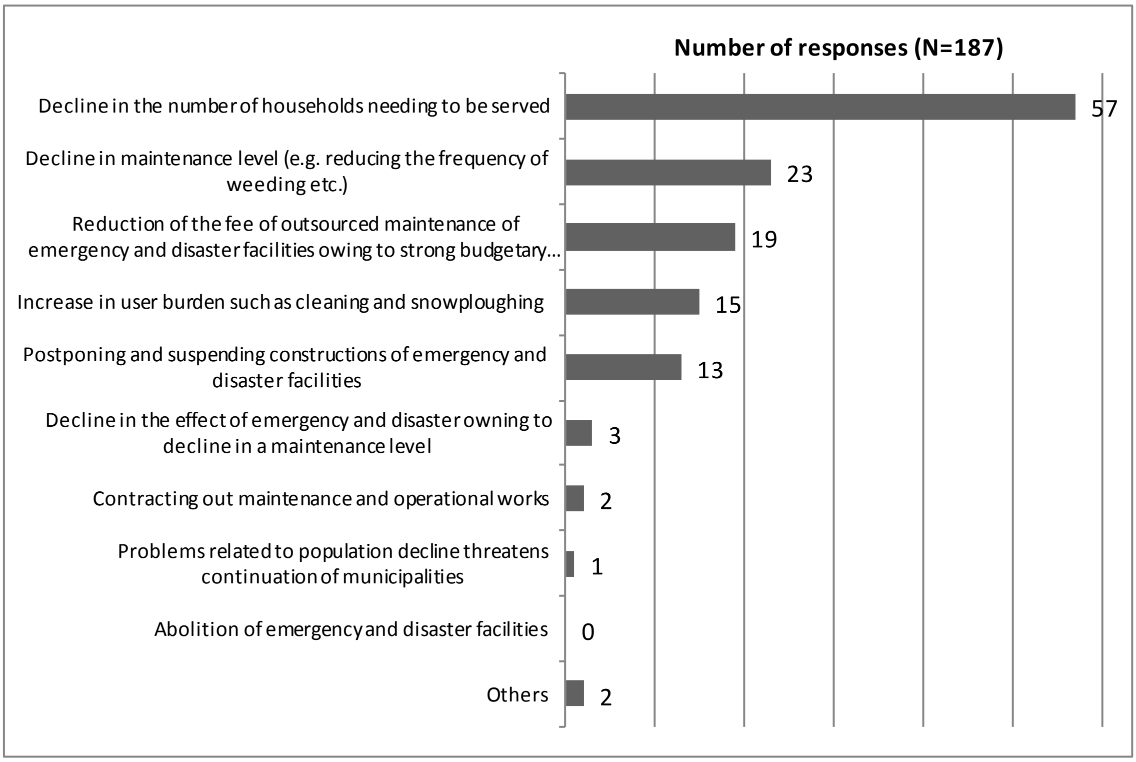


Questions for Road	No. of responses	%
Decline in maintenance levels (e.g. frequency of cleaning and snowploughing)	103	22.2%
Increase in the user burden, such as cleaning and snowploughing	75	16.2%
Occurrence of almost traffic free streets	50	10.8%
Decline in tax revenues owing to decline in sales volume of automobiles and motorcycles	45	9.7%
Reduction in traffic accidents due to decline in traffic	24	5.2%
Contracting out maintenance and operational work	17	3.7%
Mitigation of congestion due to decline in traffic	11	2.4%
Reduction in pollution, such as noise, vibration and air pollution due to decline in traffic	9	1.9%
Problems related to population decline treatens continuation of municipalities	3	0.6%
Abolition of streets in areas where there is no longer a population	2	0.4%
Somebody injured owing to a decline in maintenance levels	2	0.4%
Others	11	2.4%

Figure 84 Simple results of the impact of population decline on roads

8.3.1.7 Disaster

Descriptive results from the structured mail survey on anti-disaster facilities are shown in Figure 85. As in the transport sector, only 187 municipalities have anti-disaster facilities, because important or regional anti-disaster facilities are often developed and managed by prefectural governments or the central government in Japan. In terms of anti-disaster facilities, the number of households that need to be protected by the facilities is declining in 30.3% of municipalities, while only 12.3% of municipalities have reduced the level of maintenance of their facilities (the engineering aspect). Generally, there is not a great impact in this sector because Japan has many disasters and everybody understands the importance of sustaining anti-disaster facilities even if the number of users declines.

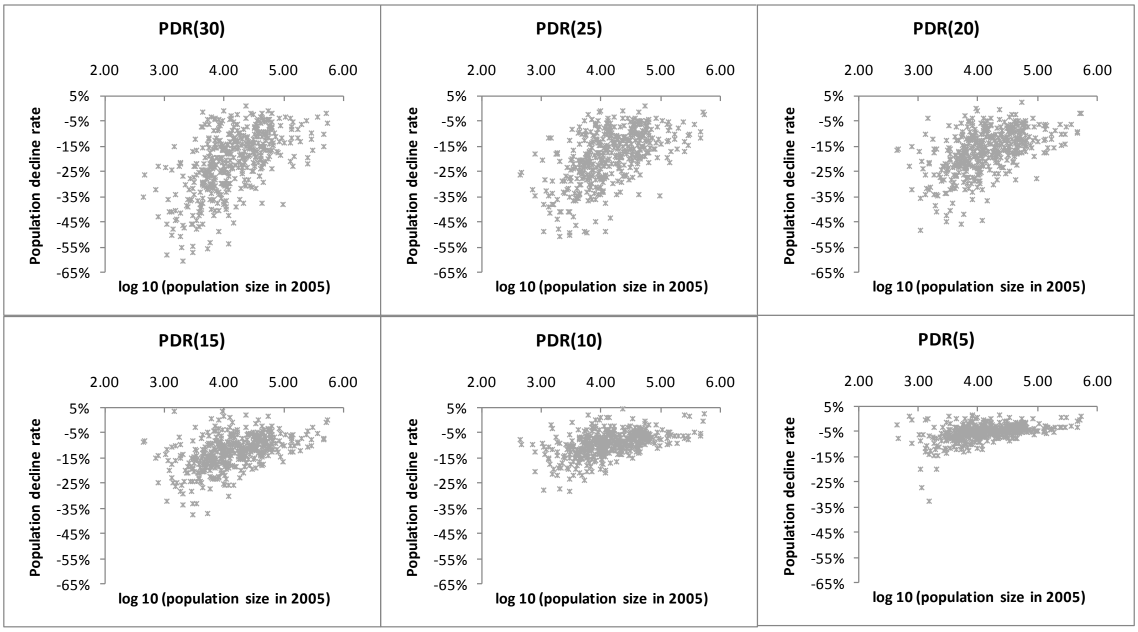


Questions for Anti-disaster facilities	No. of responses	%
Decline in the number of households needing to be served	57	30.5%
Decline in maintenance level (e.g. reducing the frequency of weeding etc.)	23	12.3%
Reduction of the fee of outsourced maintenance of emergency and disaster facilities owing to strong budgetary constraints in prefectures	19	10.2%
Increase in user burden such as cleaning and snowploughing	15	8.0%
Postponing and suspending constructions of emergency and disaster facilities	13	7.0%
Decline in the effect of emergency and disaster owning to decline in a maintenance level	3	1.6%
Contracting out maintenance and operational works	2	1.1%
Problems related to population decline threatens continuation of municipalities	1	0.5%
Abolition of emergency and disaster facilities	0	0.0%
Others	2	1.1%

Figure 85 Simple results of the impact of population decline on anti-disaster facilities

8.3.2 DESCRIPTIVE STATISTICS FOR THE INDEPENDENT VARIABLES

Figure 86 illustrates the distribution of the rate of population decline compared with the population size in log base 10. We can see a positive correlation between the rate of population decline and the population size in log base 10 in the municipalities that were sampled because the former uses the negative sign, so that a bigger population decline means a smaller number in the graph. Some outliers can be seen, but the remaining points show a population decline of less than 15% in the PDR(5) graph. By contrast, a population decline of almost 60% over 30 years is seen in the PDR(30) graph. Thus, long-term population decline has a more scattered distribution representing each municipality that was sampled.

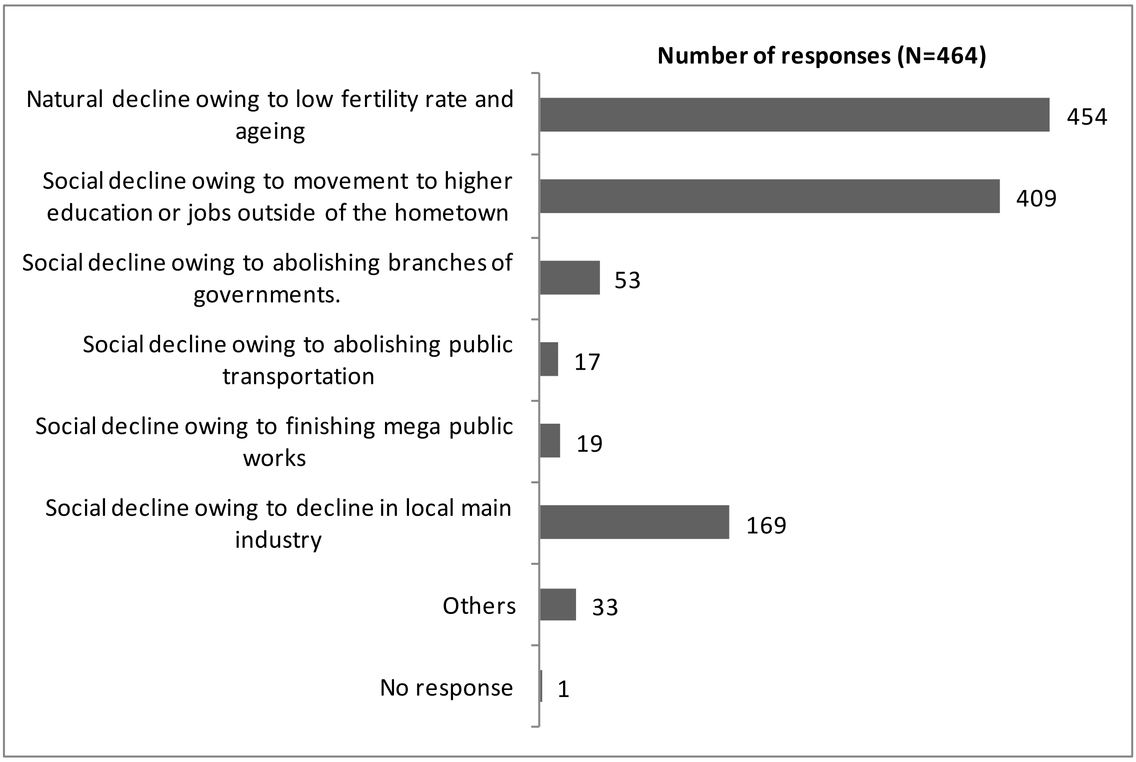


Note: PDR(30) is the rate of population decline over 30 years in a municipality.
Source: Census for each year.

Figure 86 Rate of population decline compared with population size in the sampled municipalities

Figure 87 shows the causes of population decline. Almost all sampled municipalities have experienced natural decline and social migration caused by people moving onto higher education and obtaining jobs. In terms of other causes of social migration, decline in the main industry has the highest value among responses. About 40% of sampled municipalities have experienced a decline in the main local industry, while other factors, such as closing down governmental branches/public transport and finishing large public works, have been experienced less often.

The left-hand graph in Figure 88 demonstrates the relationship between area sizes and the DID population ratio in the sampled municipalities. The dots are well scattered and there is no strong correlation between area sizes and the DID population ratio. This is because the ratio of Densely Inhabited District (DID) area to the municipality area varies depending on the location of the municipality. Even if a municipality is located on the plain, rural municipalities don't have wide DID areas, while urban municipalities located near the mountains, such as the city of Kobe, have wide DIDs. The graph on the right of Figure 88 shows that large municipalities do not have high ratios of habitable area. This means that they have many mountainous areas, and thus they may also have isolated inhabited areas and non-integrated infrastructure networks.



Source: Nomura Research Institute (2008)

Figure 87 Causes of population decline in the sampled municipalities

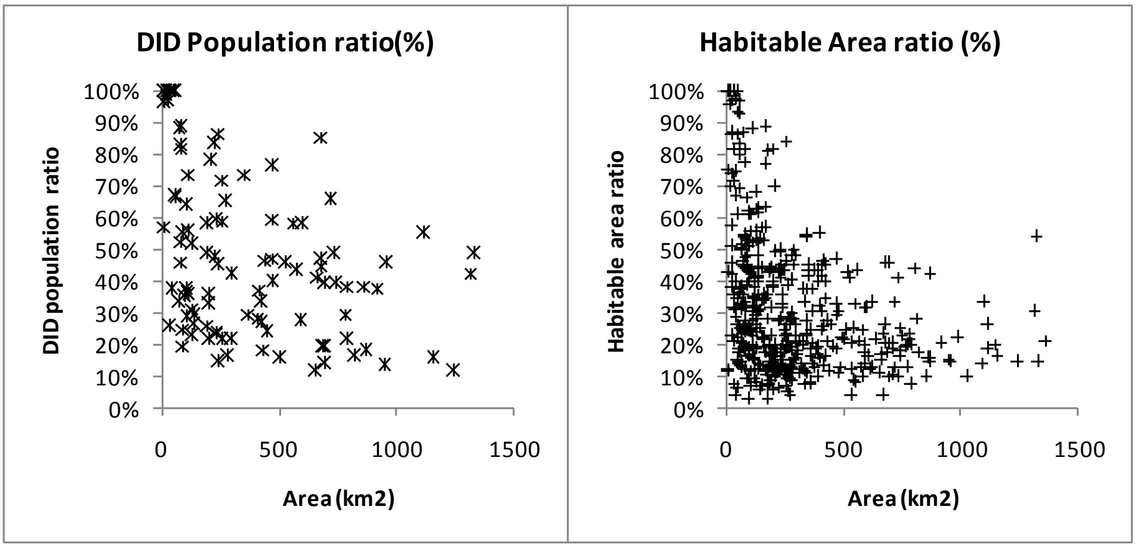


Figure 88 DID population ratio and habitable area ratio relative to the total area of the sampled municipality

Figure 89 indicates public administrative reforms. The most popular reform is to review the salary levels of public officers. Contracting out maintenance work, reviewing public services, and merging and closing down public facilities are also common choices. Generally, sampled municipalities have tackled public administrative reforms to a greater or lesser extent, so that the impact can be considered the result of these activities.

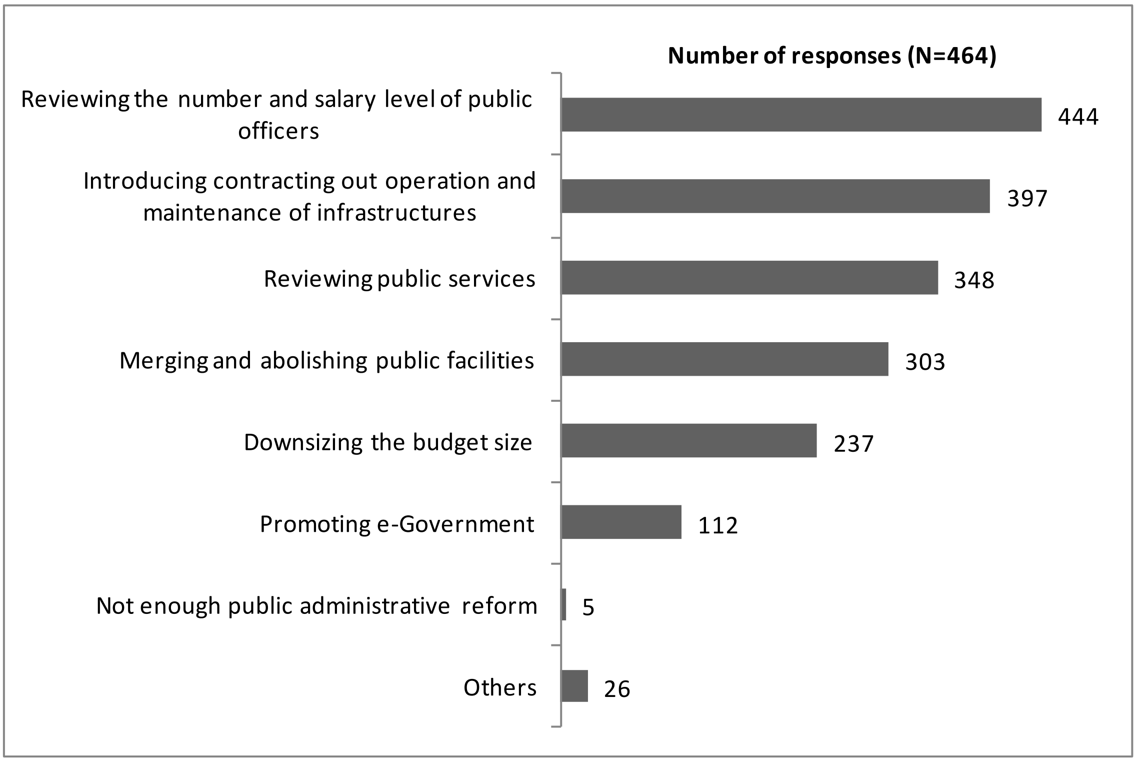
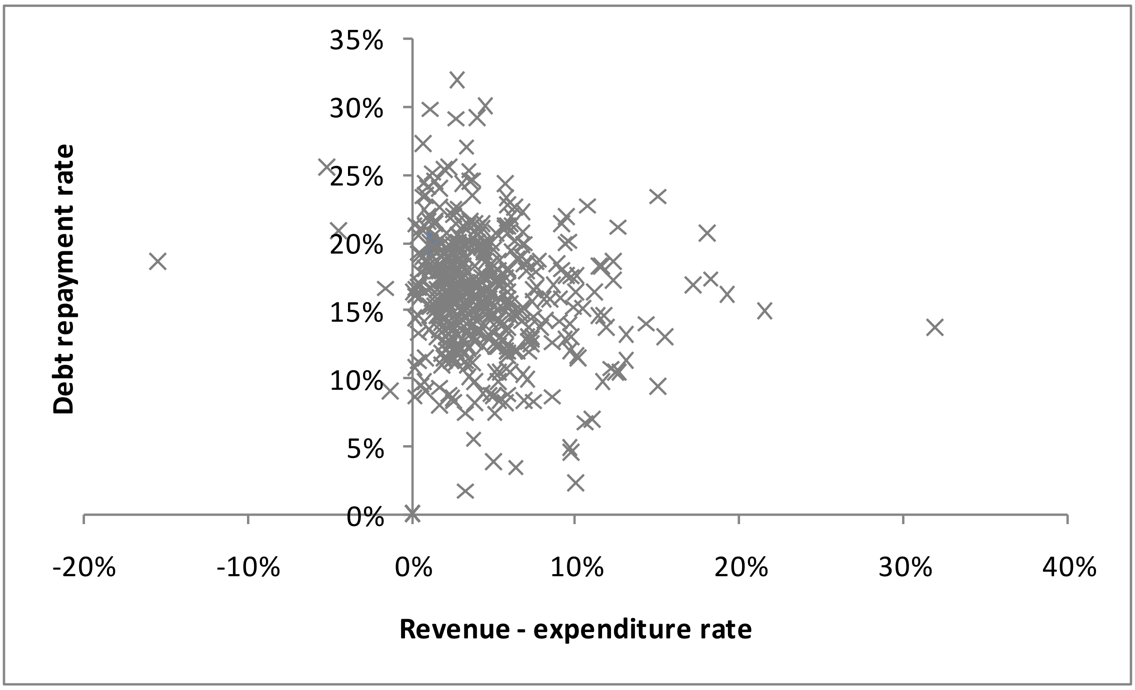


Figure 89 Current situations of public administrative reforms in sampled municipalities



Note: the definition of "debt-repayment rate" is (redemption of principal and interest payments – financial resources for redemption) /(standardised budget size) and the definition of "revenue-expenditure rate" is (revenue-expenditure)/(standardised budget size)

Figure 90 Financial situations of sampled municipalities

Finally, in terms of the financial situation in sampled municipalities, apart from some outliers, most belong to the group between the 0% to 10% ranges on the revenue-expenditure rate axis. This means that the financial situation of the most of municipalities is positive in 2008, but that they don't have enough surpluses in their financial situation. On the other hand, their debt-repayment rate is between the 10% and 25%, which suggests that around one fifth of their budget is used for the repayment of local bonds. These low revenue-expenditure rates and high debt-repayment rates cause low flexibility in the budgets of depopulating municipalities.

8.3.3 Differences between types of infrastructure

This subsection shows the key results of the first step of our analysis using the model depicted in Equation 8.2 (see Section 8.2.6.1). The main focus of this first analysis is to confirm the differences of impact between types of infrastructure. This is thought to be common sense amongst the engineering community, but there is no evidence to confirm it. This section tests whether there are indeed differential impacts amongst infrastructure types.

All the selected models shown in Table 37 are satisfactory, with a 1% statistical significance[7] for each impact type and each period of population decline. Within these significant models, the most relevant models, based on the AIC, are PDR(15) for "merging and closing down infrastructure", PDR(25) for "decline in maintenance level" and "increase in user charges", and PDR(20) for "decline in resource and energy use". This result suggests that the significant periods of population decline have different impacts and that the middle term of population decline tends to affect infrastructure.

The dummies for infrastructure types relate more or less significantly to the occurrence of these impacts. A positive relationship between the dummies and "merging and closing down facilities" and "decline in resource use" can be observed. This finding suggests that each infrastructure type affects the occurrence of the impacts positively but to different extents. In contrast, the relationship between the dummies and "decline in maintenance level" and "increase in user charges" seems to be more complex. The signs of the dummies for education facilities and public housing suggest a negative correlation between infrastructure types and the occurrence of the impacts. In other words, "decline in maintenance level" and "increase in user charges" only occur in education and public housing, while the signs and coefficients of the dummies for roads for "decline in maintenance level" and for water supply and wastewater management for "increase in user charges" suggest positive correlations.

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[7] As a way of confirming the significance and fitness indicator of the model and comparing the explanatory power of the models, the χ^2 test, Nagelkerke's R^2 (Nagelkerke 1991), and AIC were used, respectively.

Table 37 Estimation results on the model 1 with dummy variables on seven types of infrastructure

		Merging and abolishing facilities						Decline in maintenance level		Decline in resource use						Increase in user charge		
		PDR5	PDR10	PDR15	PDR20	PDR25	PDR30	Other than PDR25	PDR25	PDR5	PDR10	PDR15	PDR20	PDR25	PDR30	PDR25	PDR30	Other than PDR25, PDR30
	Model sig. (X square test)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Nagelkerke R Square	0.585	0.593	0.595	0.593	0.591	0.591	0.193	0.196	0.317	0.321	0.321	0.322	0.318	0.317	0.233	0.231	0.108
	AIC	1,264	1,252	1,246	1,251	1,254	1,255	1,352	1,351	985	980	981	980	984	985	1,188	1,189	2,363
Types	D_edu	6.839 ***	6.949 ***	6.994 ***	6.969 ***	6.947 ***	6.941 ***	-0.369 **	-0.362 **	1.527 **	1.569 ***	1.572 ***	1.577 ***	1.558 ***	1.557 ***	-0.885 ***	-0.892 ***	-1.336 ***
	D_ph	4.326 ***	4.355 ***	4.375 ***	4.368 ***	4.359 ***	4.358 ***	-0.691 ***	-0.703 ***							-1.501 ***	-1.495 ***	-0.844 ***
	D_Ls	3.717 ***	3.754 ***	3.777 ***	3.776 ***	3.767 ***	3.764 ***			1.433 **	1.471 **	1.473 **	1.477 **	1.463 **	1.462 **			
	D_ww	2.142 ***	2.160 ***	2.180 ***	2.183 ***	2.176 ***	2.173 ***			3.838 ***	3.881 ***	3.888 ***	3.895 ***	3.870 ***	3.868 ***	1.212 ***	1.207 ***	
	D_trans	2.338 ***	2.353 ***	2.354 ***	2.363 ***	2.358 ***	2.351 ***	-1.845 ***	-1.863 ***									
	D_road							1.119 ***	1.113 ***									
	D_disas																	
Demographic change	PDR5									-4.578 **								
	PDR10		-7.645 ***								-4.960 ***							
	PDR15			-6.667 ***								-3.518 ***						
	PDR20				-4.353 ***								-2.906 ***					
	PDR25					-3.364 ***			-1.531 *					-1.711 **		-1.417 *		
	PDR30						-2.850 ***								-1.372 **			
	PopSize							-0.006 **	-0.006 **							-0.007 ***	-0.008 ***	
	Elderly		-4.329 **	-5.181 ***	-4.533 ***	-4.502 **	-4.604 **	-4.193 ***	-5.428 ***	0.000 *	0.000 **	0.000 **	0.000 **	0.000 **	0.000 *			
	ND																	
	SD_ER																	
	SD_AB																	
	SD_AT															0.685 **	0.775 **	0.671 ***
	SD_FC							0.780 ***	0.670 **									
	SD_DI	0.415 **	0.318 **	0.307 *	0.302 *	0.308 *	0.318 **									0.309 *	0.362 **	
	Dec_Pat							-0.537 ***	-0.494 **									
Geography	Area	0.001 *	0.001 ***	0.001 ***	0.001 ***	0.001 ***	0.001 ***											
	DIDPop	0.915 ***	0.889 **	0.799 **	0.745 *	0.695 *	0.707 *											
	HabitableA							1.322 ***	1.381 ***							1.374 ***	1.193 ***	
	PrimeIndustry	-1.432 ***	-1.525 **	-1.800 **	-1.871 **	-1.963 **	-1.997 ***											
Stock of infrastructure	Schools															0.439 *	0.514 **	
	Housing							-1.593 ***	-1.591 ***	-1.107 *	-1.087 *	-1.159 *	-1.233 *	-1.180 *	-1.175 *			
	Facilities																	
	Parks																	
	Tanks																	
	Transport																	
	Road							-0.084 **	-0.072 *							-0.090 *	-0.103 **	
	A-Disaster							0.354 **	0.348 **							0.340 **	0.349 **	0.196 **
Public Adminstration Reform	re_P.Service							0.727 ***	0.683 ***							0.602 ***	0.654 ***	
	M&A_Facilities	NA	NA	NA	NA	NA	NA											
	Contrac-out															0.512 **	0.461 *	
	Downsize_Finance	0.404 ***	0.417 ***	0.414 ***	0.424 ***	0.424 ***	0.418 ***	0.401 ***	0.405 ***	0.492 ***	0.494 ***	0.482 ***	0.484 ***	0.489 ***	0.490 ***			
	Re_Salary																	
	e-Gov															-0.510 ***	-0.511 ***	
	Not_Enough																	
Financial Situation	Reve-Expend															-4.549 **	-4.997 **	
	Debt-Repay							3.878 **	3.839 **									
Constant		-5.782 ***	-5.216 ***	-5.057 ***	-5.097 ***	-4.974 ***	-4.895 ***	-0.111	-0.064	-3.231 ***	-3.540 ***	-3.446 ***	-3.430 ***	-3.276 ***	-3.239 ***	-2.943 ***	-2.550 ***	0.124

8.3.4 Regression results for each type of infrastructure

This subsection shows the key results of the second step of our analysis using the model depicted in Equation 8.3 (see Section 8.2.6.1.) The model presented here is a binary logit regression run on the impacts on individual types of infrastructure (that is, it does not have the infrastructure type dummy variables of the pooled model described in Section 8.3.3). The purpose of the analysis is to confirm the factors that cause the impacts in each type of infrastructure. As noted previously, only three types of infrastructure, public facilities (point-type infrastructure), water supply and wastewater management (point–network-type infrastructure), and roads (network-type infrastructure), are used from the seven types depicted in Table 2 to avoid making the description too lengthy. The descriptions of these three types of infrastructure provide the basis of the later discussion.

We consider models for several types of impact for each of the three selected infrastructure types (as per Table 33), and six periods of population decline. When the variable of population decline is not statistically significant, fewer models are estimated. The statistically selected models this time consist of the 10% statistically significant variables from the backward stepwise method or forward stepwise method. In addition, these models satisfy 5% statistical significance by the chi square test. This means that all the models shown later are statistically significant. Finally, this study only discusses the relationship between the impacts and explanatory variables, without interdependency between the latter, and it does not discuss the cause-and-effect relationship. The lowest AIC models in the various analytical results for the four aspects of infrastructure sustainability are confirmed in this section.

8.3.4.1 Public facilities

This section describes the estimation results for the public facilities from the four aspects of infrastructure sustainability.

8.3.4.1.1 Social aspect

From the social aspect, “decline in the number of users”, as shown in Table 38, and “merging and closing down facilities”, as shown in Table 39, were analysed.

Table 38 Estimation results for decline in the number of users as the social aspect of public facilities

Public facilities			PDR5		PDR10		PDR15		PDR20		PDR25		PDR30	
		Model sig. (X square test)	0.000		0.000		0.000		0.000		0.000		0.000	
		Nagelkerke R Square	0.160		0.206		0.193		0.196		0.174		0.171	
		AIC	427.602		417.463		421.469		420.817		427.547		428.420	
Category	Variables	Explanation	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance
Demographic change	PDR30	Rate of population decline between 1975 and 2005											-2.688	0.022
	PDR25	Rate of population decline between 1980 and 2005									-3.400	0.014		
	PDR20	Rate of population decline between 1985 and 2005							-7.069	0.001				
	PDR15	Rate of population decline between 1990 and 2005					-8.724	0.001						
	PDR10	Rate of population decline between 1995 and 2005			-13.872	0.000								
	PDR5	Rate of population decline between 2000 and 2005	-9.416	0.047										
	PopSize	Population in 2005 (thousands)												
	Elderly	Rate of population over 65 years old to total population in 2005			-5.754	0.061	-5.200	0.096	-5.555	0.079				
	ND	Cause of population decline: natural decline (yes=1/No=0)												
	SD_ER	Cause of population decline: higher education or recruiting (yes=1/No=0)	1.035	0.004	1.185	0.001	1.142	0.002	1.112	0.003	1.083	0.003	1.079	0.003
	SD_AB	Cause of population decline: abolishing branches (yes=1/No=0)			-0.596	0.084	-0.711	0.042	-0.808	0.024	-0.621	0.069	-0.599	0.079
	SD_AT	Cause of population decline: abolishing public transport (yes=1/No=0)	1.852	0.084	1.827	0.089	1.837	0.087	1.898	0.077	1.899	0.076	1.922	0.072
	SD_FC	Cause of population decline: finishing large public works(yes=1/No=0)												
	SD_DI	Cause of population decline: main industry decline(yes=1/No=0)												
	Dec_Pat	How population decline happens (1=partial/0=holistic)												
Geographic factors	Area	Ratio of population in the density inhabitat district to total population in 2005 （indicator of urban/rural)												
	DIDPop	Ratio of population in the density inhabitat district to total population in 2005 （indicator of urban/rural)												
	HabitableA	Ratio of habitable areas in the areas of municipality in 2006（Indicators of hardness of geography)	-1.468	0.012	-1.604	0.010	-1.679	0.007	-1.678	0.007	-1.450	0.014	-1.481	0.012
	PrimeIndustry	Ratio of population in primary industry to population between 15 years and 65 years old												
Amount of infrastructure	Schools	Number of schools per area in 2005												
	Housing	Ownership of public dwellings in 2008 (Yes=1/ No=0)												
	Facilities	Number of libraries and comminity houses per area in 2005												
	Parks	Number of parks per area in 2005												
	Tanks	Existing public transport facilities in 2008 (Yes=1/No=0)												
	Transport	Existing public transport facilities in 2008 (Yes=1/No=0)												
	Road	Road length per area in 2005 (km/km2)												
	A-Disaster	Existing anti-disaster facilities in 2008 (Yes=1/No=0)												
Public administratio	re_P.Service	Reform of public administratio services in 2008 (Yes=1/No=0)												
	M&A_Facilities	Abolishing public facilities or infrastructure in 2008 (Yes=1/No=0)												
	Contrac-out	Promoting contracting out in 2008 (Yes=1/No=0)												
	Downsize_Finance	Downsizing budget in 2008 (Yes=1/No=0)												
	Re_Salary	Reforms of salary system of municipality officers in 2008 (Yes=1/No=0)												
	e-Gov	Promoting e-government in 2008 (Yes=1/No=0)												
	Not_Enough	Insufficient public administratio reform in 2008 (Yes=1/No=0)	-21.652	0.999			-21.530	0.999	-21.514	0.999	-21.603	0.999	-21.631	0.999
Financial situation	Reve-Expend	Ratio of general revenue and expenditure balance in 2005												
	Debt-Repay	Ratio of debt repayment in 2005												
Constant			-0.171	0.730	0.776	0.422	0.880	0.366	0.947	0.332	-0.268	0.593	-0.174	0.723

Table 39 Estimation results for merging and closing down facilities as the social aspect of public facilities

Public facilities			PDR5/15/30		PDR10		PDR20		PDR25	
		Model sig. (X square test)	0.000		0.000		0.000		0.000	
		Nagelkerke R Square	0.151		0.134		0.138		0.136	
		AIC	345.559		349.887		348.831		349.370	
Category	Variables	Explanation	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance
Demographic change	PDR30	Rate of population decline between 1975 and 2005								
	PDR25	Rate of population decline between 1980 and 2005							-2.869	0.029
	PDR20	Rate of population decline between 1985 and 2005					-3.640	0.022		
	PDR15	Rate of population decline between 1990 and 2005								
	PDR10	Rate of population decline between 1995 and 2005			-5.906	0.040				
	PDR5	Rate of population decline between 2000 and 2005								
	PopSize	Population in 2005 (thousands)								
	Elderly	Rate of population over 65 years old to total population in 2005								
	ND	Cause of population decline: natural decline (yes=1/No=0)								
	SD_ER	Cause of population decline: higher education or recruiting (yes=1/No=0)	-0.946	0.024	-0.761	0.066	-0.783	0.060	-0.770	0.064
	SD_AB	Cause of population decline: abolishing branches (yes=1/No=0)								
	SD_AT	Cause of population decline: abolishing public transport (yes=1/No=0)								
	SD_FC	Cause of population decline: finishing large public works(yes=1/No=0)								
	SD_DI	Cause of population decline: main industry decline(yes=1/No=0)								
	Dec_Pat	How population decline happens (1=partial/0=holistic)								
Geographic factors	Area	Areas of municipaliteis (km^2)	0.001	0.068	0.002	0.001	0.002	0.001	0.002	0.001
	DIDPop	Ratio of population in the density inhabitat district to total population in 2005 （indicator of urban/rural)	2.167	0.004	1.191	0.044	1.187	0.044	1.168	0.047
	HabitableA	Ratio of habitable areas in the areas of municipality in 2006（Indicators of hardness of geography)								
	PrimeIndustry	Ratio of population in primary industry to population between 15 years and 65 years old								
Amount of infrastructure	Schools	Number of schools per area in 2005	-2.604	0.056						
	Housing	Ownership of public dwellings in 2008 (Yes=1/ No=0)								
	Facilities	Number of libraries and comminity houses per area in 2005								
	Parks	Number of parks per area in 2005								
	Tanks	Number of septic tanks per area in 2004								
	Transport	Existing public transport facilities in 2008 (Yes=1/No=0)								
	Road	Road length per area in 2005 (km/km2)								
	A-Disaster	Existing anti-disaster facilities in 2008 (Yes=1/No=0)								
Public administratio	re_P.Service	Reform of public administratio services in 2008 (Yes=1/No=0)								
	M&A_Facilities	Abolishing public facilities or infrastructure in 2008 (Yes=1/No=0)								
	Contrac-out	Promoting contracting out in 2008 (Yes=1/No=0)								
	Downsize_Finance	Downsizing budget in 2008 (Yes=1/No=0)	0.561	0.048	0.547	0.054	0.538	0.058	0.534	0.060
	Re_Salary	Reforms of salary system of municipality officers in 2008 (Yes=1/No=0)								
	e-Gov	Promoting e-government in 2008 (Yes=1/No=0)								
	Not_Enough	Insufficient public administratio reform in 2008 (Yes=1/No=0)								
Financial situation	Reve-Expend	Ratio of general revenue and expenditure balance in 2005								
	Debt-Repay	Ratio of debt repayment in 2005	6.900	0.034	7.597	0.018	7.554	0.019	7.601	0.018
Constant			-2.244	0.002	-3.566	0.000	-3.594	0.000	-3.535	0.000

8.3.4.1.1.1 Decline in the number of users

In Table 38, in terms of the "decline in the number of users", the PDR(10) model, considering the population decline over 10 years, is the most valid, based on the AIC, although all the models from PDR(5) to PDR(30) statistically significantly include the variable on population decline.

The PDR(10) model shows, with 10% statistical significance, that the variable "Elderly", which is the ratio of the population who were over 65 years old in 2005, is a negative coefficient; "SD_ER", which is moving to higher education and obtaining jobs as a cause of population decline, is a positive coefficient; "SD_AB", which is closing down branch offices as a cause of population decline, is a negative coefficient; "SD_AT", which is closing down public transport as a cause of population decline, is a positive coefficient; and "HabitableA", which is habitable areas, is a negative coefficient. The magnitude of these coefficients also suggests that there is a strong correlation between the decline in the number of users of public facilities and 10 year population decline. The results suggest that if a municipality experiences outmigration owing to a lack of higher education opportunities and the closure of branch offices and public transport in small habitable areas, a decline in the number of users of public facilities will occur.

8.3.4.1.1.2 Merging and closure

In Table 39, not only is the model without the variables on population decline significant, but the PDR(10), PDR(20), and PDR(25) models on merging and closing down public facilities are also significant. The AIC, however, suggests that the model without the variables of population decline is the most valid.

This model shows the variable "SD_ER", which is moving to higher education and obtaining jobs as the cause of population decline, to be a negative coefficient; "Area", which is the area of the municipality, and "DIDPop", which is the ratio of the population in densely populated areas to the total population in the municipality, to be positive coefficients; "Schools", which is the number of schools per unit area of the municipality, to be a negative coefficient; and "Downsize_Finance", which shows whether the municipality has decreased its budget, to be a positive coefficient.

These results suggest that regardless of the extent of population decline, once a municipality with a wide area that is densely inhabited, and with few schools but facilities for higher education, such as high schools and universities, faces constraints on its budget, it will consider merging and closing down public facilities. This may be because those municipalities have many public facilities located close to each other, and they can restructure the location of public facilities while still maintaining the public service level.

8.3.4.1.2 Engineering aspect

From the engineering aspect, "contracting out O&M work", as shown in Table 40, and "decline in the level of maintenance", as shown in Table 41, were analysed.

8.3.4.1.2.1 Contracting out O&M work

The estimation result suggests that "contracting out O&M work" does not relate to population decline. By contrast, "Elderly", which is the ratio of the elderly to the total population, is a negative coefficient; "DIDPop", which is the ratio of the population to the total population in the municipality, is a positive coefficient; "Schools", which is the number of schools per area in the municipality, is a negative coefficient; "Housing", which means the ownership of public housing by municipalities, and "Facilities", which is the number of public facilities such as libraries per municipality area, are positive coefficients that can affect the infrastructure. Therefore, municipalities in relatively urban areas and those that have a large quantity of public housing and facilities contract out more O&M work for their infrastructure. These municipalities do not, however, necessarily conduct governmental administrative reforms and no particular trends in their financial situations could be found. This finding suggests that contracting out the O&M of public facilities is not undertaken either because of financial difficulties or because of the difficulty of the O&M of the facilities, but because contracting out is the usual procedure for the management of these facilities.

Table 40 Estimation results for contracting out O&M work as an engineering aspect of public facilities

Public facilities			PDR5/10/15/20/25/30	
		Model sig. (X square test)	0.000	
		Nagelkerke R Square	0.082	
		AIC	497.413	
Category	Variables	Explanation	Coefficients	Probability of significance
Demographic change	PDR30	Rate of population decline between 1975 and 2005		
	PDR25	Rate of population decline between 1980 and 2005		
	PDR20	Rate of population decline between 1985 and 2005		
	PDR15	Rate of population decline between 1990 and 2005		
	PDR10	Rate of population decline between 1995 and 2005		
	PDR5	Rate of population decline between 2000 and 2005		
	PopSize	Population in 2005 (thousands)		
	Elderly	Rate of population over 65 years old to total population in 2005	-5.291	0.021
	ND	Cause of population decline: natural decline (yes=1/No=0)		
	SD_ER	Cause of population decline: higher education or recruiting (yes=1/No=0)		
	SD_AB	Cause of population decline: abolishing branches (yes=1/No=0)		
	SD_AT	Cause of population decline: abolishing public transport (yes=1/No=0)		
	SD_FC	Cause of population decline: finishing large public works(yes=1/No=0)		
	SD_DI	Cause of population decline: main industry decline(yes=1/No=0)		
	Dec_Pat	How population decline happens (1=partial/0=holistic)		
Geographic factors	Area	Areas of municipaliteis (km^2)		
	DIDPop	Ratio of population in the density inhabitat district to total population in 2005 （indicator of urban/rural)	1.646	0.011
	HabitableA	Ratio of habitable areas in the areas of municipality in 2006（Indicators of hardness of geography)		
	PrimeIndustry	Ratio of population in primary industry to population between 15 years and 65 years old		
Amount of infrastructure	Schools	Number of schools per area in 2005	-0.715	0.042
	Housing	Ownership of public dwellings in 2008 (Yes=1/ No=0)	2.369	0.040
	Facilities	Number of libraries and comminity houses per area in 2005	2.614	0.083
	Parks	Number of parks per area in 2005		
	Tanks	Number of septic tanks per area in 2004		
	Transport	Existing public transport facilities in 2008 (Yes=1/No=0)		
	Road	Road length per area in 2005 (km/km2)		
	A-Disaster	Existing anti-disaster facilities in 2008 (Yes=1/No=0)		
Public administratio	re_P.Service	Reform of public administratio services in 2008 (Yes=1/No=0)		
	M&A_Facilities	Abolishing public facilities or infrastructure in 2008 (Yes=1/No=0)		
	Contrac-out	Promoting contracting out in 2008 (Yes=1/No=0)		
	Downsize_Finance	Downsizing budget in 2008 (Yes=1/No=0)		
	Re_Salary	Reforms of salary system of municipality officers in 2008 (Yes=1/No=0)		
	e-Gov	Promoting e-government in 2008 (Yes=1/No=0)		
	Not_Enough	Insufficient public administratio reform in 2008 (Yes=1/No=0)		
Financial situation	Reve-Expend	Ratio of general revenue and expenditure balance in 2005		
	Debt-Repay	Ratio of debt repayment in 2005		
Constant			-1.091	0.414

Table 41 Estimation results for the decline in the level of maintenance as an engineering aspect of public facilities

Public facilities			PDR5/20/25/30		PDR10		PDR15	
		Model sig. (X square test)	0.000		0.000		0.000	
		Nagelkerke R Square	0.100		0.118		0.087	
		AIC	372.083		371.218		373.375	
Category	Variables	Explanation	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance
Demographic change	PDR30	Rate of population decline between 1975 and 2005						
	PDR25	Rate of population decline between 1980 and 2005						
	PDR20	Rate of population decline between 1985 and 2005						
	PDR15	Rate of population decline between 1990 and 2005						
	PDR10	Rate of population decline between 1995 and 2005			-5.239	0.091		
	PDR5	Rate of population decline between 2000 and 2005						
	PopSize	Population in 2005 (thousands)						
	Elderly	Rate of population over 65 years old to total population in 2005						
	ND	Cause of population decline: natural decline (yes=1/No=0)						
	SD_ER	Cause of population decline: higher education or recruiting (yes=1/No=0)						
	SD_AB	Cause of population decline: abolishing branches (yes=1/No=0)						
	SD_AT	Cause of population decline: abolishing public transport (yes=1/No=0)						
	SD_FC	Cause of population decline: finishing large public works(yes=1/No=0)	1.144	0.031	0.958	0.083	1.080	0.041
	SD_DI	Cause of population decline: main industry decline(yes=1/No=0)						
	Dec_Pat	How population decline happens (1=partial/0=holistic)						
Geographic factors	Area	Areas of municipaliteis (km^2)						
	DIDPop	Ratio of population in the density inhabitat district to total population in 2005 （indicator of urban/rural)			1.562	0.030		
	HabitableA	Ratio of habitable areas in the areas of municipality in 2006（Indicators of hardness of geography)	2.556	0.000	2.463	0.000	1.693	0.003
	PrimeIndustry	Ratio of population in primary industry to population between 15 years and 65 years old						
Amount of infrastructure	Schools	Number of schools per area in 2005						
	Housing	Ownership of public dwellings in 2008 (Yes=1/ No=0)						
	Facilities	Number of libraries and comminity houses per area in 2005			-0.854	0.082		
	Parks	Number of parks per area in 2005						
	Tanks	Number of septic tanks per area in 2004						
	Transport	Existing public transport facilities in 2008 (Yes=1/No=0)						
	Road	Road length per area in 2005 (km/km2)	-0.146	0.031				
	A-Disaster	Existing anti-disaster facilities in 2008 (Yes=1/No=0)						
Public administratio	re_P.Service	Reform of public administratio services in 2008 (Yes=1/No=0)	0.760	0.046	0.767	0.042	0.819	0.027
	M&A_Facilities	Abolishing public facilities or infrastructure in 2008 (Yes=1/No=0)						
	Contrac-out	Promoting contracting out in 2008 (Yes=1/No=0)						
	Downsize_Finance	Downsizing budget in 2008 (Yes=1/No=0)	0.478	0.084				
	Re_Salary	Reforms of salary system of municipality officers in 2008 (Yes=1/No=0)						
	e-Gov	Promoting e-government in 2008 (Yes=1/No=0)						
	Not_Enough	Insufficient public administratio reform in 2008 (Yes=1/No=0)						
Financial situation	Reve-Expend	Ratio of general revenue and expenditure balance in 2005						
	Debt-Repay	Ratio of debt repayment in 2005			5.454	0.070	5.898	0.046
Constant			-2.779	0.000	-4.306	0.000	-3.575	0.000

8.3.4.1.2.2 Decline in the level of maintenance

The impact of population decline on the level of infrastructure maintenance can only be seen in the PDR(10) model, which considers changes over 10 years of population decline; this model also has the smallest AIC among the estimated models. The estimation result suggests that “contracting out O&M work” does not relate to population decline. The model can be considered the best model for the impact.

This model also includes positive coefficients for “SD_FC”, which is the completion of huge public construction works, and “DIDpop”, which is the ratio of the population to the total population in the municipality, “HabitableA”, which are the habitable areas, “re_P.Service”, which means that the municipalities have reviewed their policies, and “Debt-Repay”, which is the rate of repayment by the municipality, and a negative coefficient for “Facilities”.

This finding suggests that those municipalities with wider and flatter areas, a high-density population but fewer public facilities, which experience a specific cause of population decline, such as the completion of huge public works, and have reviewed their public administrative services owing to the budgetary constraints of a high rate of debt repayment, will still experience a decline in the level of maintenance.

8.3.4.1.3 Environmental aspect

As an environmental aspect, “Energy and resource consumption”, as shown in Table 42, was analysed.

8.3.4.1.3.1 Energy and resource consumption

As the results of the estimations show, PDR(10), PDR(15), PDR(20), and PDR(25) all survive the statistical testing, and the AIC of PDR(20) is the smallest and most valid regarding the decline in the consumption of energy and resources.

This PDR(20) model also includes negative coefficients for “SD_DI” and “Housing”. This finding suggests that utility costs can decline in municipalities located in suburbs with enough private accommodation but fewer public dwellings, and which have experienced a stable economic situation without industrial decline.

Table 42 Estimation results for energy and resource consumption as the environmental aspect of public facilities

Public facilities			PDR5		PDR10		PDR15		PDR20		PDR25		PDR30	
		Model sig. (X square test)	0.004		0.001		0.002		0.001		0.002		0.004	
		Nagelkerke R Square	0.086		0.138		0.082		0.110		0.113		0.086	
		AIC	231.100		227.500		229.700		226.600		230.000		231.100	
Category	Variables	Explanation	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance
Demographic change	PDR30	Rate of population decline between 1975 and 2005												
	PDR25	Rate of population decline between 1980 and 2005									-3.626	0.096		
	PDR20	Rate of population decline between 1985 and 2005							-7.904	0.000				
	PDR15	Rate of population decline between 1990 and 2005					-8.090	0.002						
	PDR10	Rate of population decline between 1995 and 2005			-9.517	0.033								
	PDR5	Rate of population decline between 2000 and 2005												
	PopSize	Population in 2005 (thousands)												
	Elderly	Rate of population over 65 years old to total population in 2005	10.884	0.001	8.277	0.041					8.581	0.040	10.884	0.001
	ND	Cause of population decline: natural decline (yes=1/No=0)												
	SD_ER	Cause of population decline: higher education or recruiting (yes=1/No=0)												
	SD_AB	Cause of population decline: abolishing branches (yes=1/No=0)												
	SD_AT	Cause of population decline: abolishing public transport (yes=1/No=0)												
	SD_FC	Cause of population decline: finishing large public works(yes=1/No=0)												
	SD_DI	Cause of population decline: main industry decline(yes=1/No=0)			-0.845	0.051			-0.729	0.078	-0.782	0.070		
	Dec_Pat	How population decline happens (1=partial/0=holistic)												
Geographic factors	Area	Ratio of population in the density inhabitat district to total population in 2005 （indicator of												
	DIDPop	Ratio of population in the density inhabitat district to total population in 2005 （indicator of	1.685	0.049	1.855	0.032					1.804	0.037	1.685	0.049
	HabitableA	Ratio of habitable areas in the areas of municipality in 2006（Indicators of hardness of geography)												
	PrimeIndustry	Ratio of population in primary industry to population between 15 years and 65 years old												
Amount of infrastructure	Schools	Number of schools per area in 2005												
	Housing	Ownership of public dwellings in 2008 (Yes=1/ No=0)	-1.970	0.028	-1.960	0.041	-1.928	0.039	-2.081	0.030	-2.133	0.021	-1.970	0.028
	Facilities	Number of libraries and comminity houses per area in 2005												
	Parks	Number of parks per area in 2005												
	Tanks	Existing public transport facilities in 2008 (Yes=1/No=0)												
	Transport	Existing public transport facilities in 2008 (Yes=1/No=0)												
	Road	Road length per area in 2005 (km/km2)												
	A-Disaster	Existing anti-disaster facilities in 2008 (Yes=1/No=0)												
Public administratio	re_P.Service	Reform of public administratio services in 2008 (Yes=1/No=0)												
	M&A_Facilities	Abolishing public facilities or infrastructure in 2008 (Yes=1/No=0)												
	Contrac-out	Promoting contracting out in 2008 (Yes=1/No=0)												
	Downsize_Finance	Downsizing budget in 2008 (Yes=1/No=0)												
	Re_Salary	Reforms of salary system of municipality officers in 2008 (Yes=1/No=0)												
	e-Gov	Promoting e-government in 2008 (Yes=1/No=0)												
	Not_Enough	Insufficient public administratio reform in 2008 (Yes=1/No=0)												
Financial situation	Reve-Expend	Ratio of general revenue and expenditure balance in 2005												
	Debt-Repay	Ratio of debt repayment in 2005												
Constant			-4.123	0.001	-5.224	0.001	-2.778	0.019	-2.897	0.015	-3.802	0.007	-4.123	0.001

8.3.4.1.4 Economic aspect

8.3.4.1.4.1 Increase in user charge

Of the economic aspects, "Increase in user charges", as shown in Table 43, was analysed.

The estimation result suggests that there is no relationship between the rate of population decline and the increase in the user financial burden. By contrast, the valid model includes a negative coefficient for "Elderly" and positive coefficients for "SD_AT", "SD_DI", "HabitableA", "PrimeIndustry", and "re_P.Service". Accordingly, municipalities located on flat and agricultural areas without public transport but where younger people are living, having reviewed their administrative services, will increase their user charges.

Table 43 Estimation results for an increase in user charges as the economic aspect of public facilities

Public facilities			PDR5/10/15/20/25/30	
		Model sig. (X square test)	0.000	
		Nagelkerke R Square	0.142	
		AIC	334.435	
Category	Variables	Explanation	Coefficients	Probability of significance
Demographic change	PDR30	Rate of population decline between 1975 and 2005		
	PDR25	Rate of population decline between 1980 and 2005		
	PDR20	Rate of population decline between 1985 and 2005		
	PDR15	Rate of population decline between 1990 and 2005		
	PDR10	Rate of population decline between 1995 and 2005		
	PDR5	Rate of population decline between 2000 and 2005		
	PopSize	Population in 2005 (thousands)		
	Elderly	Rate of population over 65 years old to total population in 2005	-7.862	0.018
	ND	Cause of population decline: natural decline (yes=1/No=0)		
	SD_ER	Cause of population decline: higher education or recruiting (yes=1/No=0)		
	SD_AB	Cause of population decline: abolishing branches (yes=1/No=0)		
	SD_AT	Cause of population decline: abolishing public transport (yes=1/No=0)	1.369	0.014
	SD_FC	Cause of population decline: finishing large public works(yes=1/No=0)		
	SD_DI	Cause of population decline: main industry decline(yes=1/No=0)	0.571	0.059
	Dec_Pat	How population decline happens (1=partial/0=holistic)		
Geographic factors	Area	Areas of municipaliteis (km^2)		
	DIDPop	Ratio of population in the density inhabitat district to total population in 2005 （indicator of urban/rural)		
	HabitableA	Ratio of habitable areas in the areas of municipality in 2006（Indicators of hardness of geography)	1.290	0.050
	PrimeIndustry	Ratio of population in primary industry to population between 15 years and 65 years old	4.370	0.001
Amount of infrastructure	Schools	Number of schools per area in 2005		
	Housing	Ownership of public dwellings in 2008 (Yes=1/ No=0)		
	Facilities	Number of libraries and comminity houses per area in 2005		
	Parks	Number of parks per area in 2005		
	Tanks	Number of septic tanks per area in 2004		
	Transport	Existing public transport facilities in 2008 (Yes=1/No=0)		
	Road	Road length per area in 2005 (km/km2)		
	A-Disaster	Existing anti-disaster facilities in 2008 (Yes=1/No=0)		
Public administratio	re_P.Service	Reform of public administratio services in 2008 (Yes=1/No=0)	0.718	0.062
	M&A_Facilities	Abolishing public facilities or infrastructure in 2008 (Yes=1/No=0)		
	Contrac-out	Promoting contracting out in 2008 (Yes=1/No=0)		
	Downsize_Finance	Downsizing budget in 2008 (Yes=1/No=0)		
	Re_Salary	Reforms of salary system of municipality officers in 2008 (Yes=1/No=0)		
	e-Gov	Promoting e-government in 2008 (Yes=1/No=0)		
	Not_Enough	Insufficient public administratio reform in 2008 (Yes=1/No=0)		
Financial situation	Reve-Expend	Ratio of general revenue and expenditure balance in 2005		
	Debt-Repay	Ratio of debt repayment in 2005		
Constant			-1.353	0.224

8.3.4.2 Water and wastewater

This section describes the estimation results for the water supply and wastewater management infrastructure from the four aspects of infrastructure sustainability.

8.3.4.2.1 Social aspect

8.3.4.2.1.1 Merging and closing down facilities

“Merging and closing down facilities”, as shown in Table 44, was analysed as a social aspect.

Table 44 Estimation results for merging and closing down facilities as the social aspect of water and wastewater management

Water supply and waste water management			PDR5/10/15/20/25/30	
		Model sig. (X square test)	0.000	
		Nagelkerke R Square	0.215	
		AIC	116.228	
Category	Variables	Explanation	Coefficients	Probability of significance
Demographic change	PDR30	Rate of population decline between 1975 and 2005		
	PDR25	Rate of population decline between 1980 and 2005		
	PDR20	Rate of population decline between 1985 and 2005		
	PDR15	Rate of population decline between 1990 and 2005		
	PDR10	Rate of population decline between 1995 and 2005		
	PDR5	Rate of population decline between 2000 and 2005		
	PopSize	Population in 2005 (thousands)		
	Elderly	Rate of population over 65 years old to total population in 2005		
	ND	Cause of population decline: natural decline (yes=1/No=0)		
	SD_ER	Cause of population decline: higher education or recruiting (yes=1/No=0)		
	SD_AB	Cause of population decline: abolishing branches (yes=1/No=0)		
	SD_AT	Cause of population decline: abolishing public transport (yes=1/No=0)		
	SD_FC	Cause of population decline: finishing large public works(yes=1/No=0)		
	SD_DI	Cause of population decline: main industry decline(yes=1/No=0)		
	Dec_Pat	How population decline happens (1=partial/0=holistic)		
Geographic factors	Area	Areas of municipaliteis (km^2)		
	DIDPop	Ratio of population in the density inhabitat district to total population in 2005 （indicator of		
	HabitableA	Ratio of habitable areas in the areas of municipality in 2006（Indicators of hardness of geography)		
	PrimeIndustry	Ratio of population in primary industry to population between 15 years and 65 years old	-8.020	0.010
Amount of infrastructure	Schools	Number of schools per area in 2005		
	Housing	Ownership of public dwellings in 2008 (Yes=1/ No=0)		
	Facilities	Number of libraries and comminity houses per area in 2005	-10.746	0.062
	Parks	Number of parks per area in 2005		
	Tanks	Number of septic tanks per area in 2004	6.332	0.041
	Transport	Existing public transport facilities in 2008 (Yes=1/No=0)	1.664	0.002
	Road	Road length per area in 2005 (km/km2)		
	A-Disaster	Existing anti-disaster facilities in 2008 (Yes=1/No=0)		
Public administratio	re_P.Service	Reform of public administratio services in 2008 (Yes=1/No=0)		
	M&A_Facilities	Abolishing public facilities or infrastructure in 2008 (Yes=1/No=0)		
	Contrac-out	Promoting contracting out in 2008 (Yes=1/No=0)		
	Downsize_Finance	Downsizing budget in 2008 (Yes=1/No=0)		
	Re_Salary	Reforms of salary system of municipality officers in 2008 (Yes=1/No=0)		
	e-Gov	Promoting e-government in 2008 (Yes=1/No=0)		
	Not_Enough	Insufficient public administratio reform in 2008 (Yes=1/No=0)		
Financial situation	Reve-Expend	Ratio of general revenue and expenditure balance in 2005		
	Debt-Repay	Ratio of debt repayment in 2005		
Constant			-2.218	0.000

The estimation results suggest that there are no relationships between merging and closing down water-related infrastructure and demographic factors such as population decline, the causes of population decline, population size, or the situation of the elderly. By contrast, the industrial situation, such as a low rate of employment in the agricultural sector, which can imply that the area is an urban area, can more usually cause the merging and closure of water-related infrastructure. This may be because there are multiple facilities, enabling the manager to reduce their number; municipalities that cannot have multiple facilities, because they only have a limited number of users, cannot carry out the merging and closure of facilities even when they experience a decline in the amount of water consumed. Of course, the options will change once the local authority has merged water supply and wastewater management facilities.

8.3.4.2.2 Engineering aspect

As an engineering aspect, “contracting out O&M work”, shown in Table 45, was analysed.

8.3.4.2.2.1 Contracting out O&M work

The PDR(20) model can include the PDR variables for contracting out the O&M of water-related infrastructure. The indices on fitness and statistical significance between the models with the PDR variables and those without the variables do not show any remarkable differences, but those indices suggest that the model without the PDR variables should be a better model than that with the PDR variables.

Table 45 Estimation results for contracting out O&M work as the engineering aspect of water and wastewater management

Water supply and waste water management			PDR5/10/15/25/30		PDR20	
		Model sig. (X square test)	0.004		0.003	
		Nagelkerke R Square	0.080		0.083	
		AIC	334.011		333.369	
Category	Variables	Explanation	Coefficients	Probability of significance	Coefficients	Probability of significance
Demographic change	PDR30	Rate of population decline between 1975 and 2005				
	PDR25	Rate of population decline between 1980 and 2005				
	PDR20	Rate of population decline between 1985 and 2005			3.094	0.077
	PDR15	Rate of population decline between 1990 and 2005				
	PDR10	Rate of population decline between 1995 and 2005				
	PDR5	Rate of population decline between 2000 and 2005				
	PopSize	Population in 2005 (thousands)				
	Elderly	Rate of population over 65 years old to total population in 2005				
	ND	Cause of population decline: natural decline (yes=1/No=0)				
	SD_ER	Cause of population decline: higher education or recruiting (yes=1/No=0)				
	SD_AB	Cause of population decline: abolishing branches (yes=1/No=0)				
	SD_AT	Cause of population decline: abolishing public transport (yes=1/No=0)				
	SD_FC	Cause of population decline: finishing large public works(yes=1/No=0)				
	SD_DI	Cause of population decline: main industry decline(yes=1/No=0)	0.500	0.073	0.530	0.061
	Dec_Pat	How population decline happens (1=partial/0=holistic)				
Geographic factors	Area	Areas of municipaliteis (km^2)				
	DIDPop	Ratio of population in the density inhabitat district to total population in 2005 （indicator of				
	HabitableA	Ratio of habitable areas in the areas of municipality in 2006（Indicators of hardness of geography)	-1.766	0.046	-2.173	0.022
	PrimeIndustry	Ratio of population in primary industry to population between 15 years and 65 years old				
Amount of infrastructure	Schools	Number of schools per area in 2005				
	Housing	Ownership of public dwellings in 2008 (Yes=1/ No=0)				
	Facilities	Number of libraries and comminity houses per area in 2005			-5.567	0.077
	Parks	Number of parks per area in 2005				
	Tanks	Number of septic tanks per area in 2004	3.629	0.029	5.839	0.010
	Transport	Existing public transport facilities in 2008 (Yes=1/No=0)				
	Road	Road length per area in 2005 (km/km2)				
	A-Disaster	Existing anti-disaster facilities in 2008 (Yes=1/No=0)				
Public administratio	re_P.Service	Reform of public administratio services in 2008 (Yes=1/No=0)				
	M&A_Facilities	Abolishing public facilities or infrastructure in 2008 (Yes=1/No=0)				
	Contrac-out	Promoting contracting out in 2008 (Yes=1/No=0)				
	Downsize_Finance	Downsizing budget in 2008 (Yes=1/No=0)				
	Re_Salary	Reforms of salary system of municipality officers in 2008 (Yes=1/No=0)				
	e-Gov	Promoting e-government in 2008 (Yes=1/No=0)				
	Not_Enough	Insufficient public administratio reform in 2008 (Yes=1/No=0)	22.696	1.000		
Financial situation	Reve-Expend	Ratio of general revenue and expenditure balance in 2005				
	Debt-Repay	Ratio of debt repayment in 2005	5.223	0.072		
Constant			-1.966	0.001	-0.268	0.574

Common explanatory variables for all the models include the variables on industrial decline as a cause of population decline. The regions that have experienced industrial decline therefore promote contracting out maintenance work for infrastructure in the water sector.

In terms of geographical factors, a negative relationship between contracting out and the proportion of habitable areas could be found. This means that a region with difficult terrain will promote contracting out, but it does not suggest that a rural area will promote contracting out because we could not find any significant relationship between the variables on population size and the rate of DID population, which are the indices for urbanisation and contracting out. In addition, in PDR(20) the variable for the number of public facilities is negative. If urban municipalities promote contracting out, that variable should be positive. Thus urbanisation is not a key factor in promoting contracting out in the water sector. Municipalities with many septic tanks, where wastewater management facilities have not been developed, could begin to promote contracting out.

8.3.4.2.3 Environmental aspect

As an environmental aspect, “decline in resource consumption”, as shown in Table 45, was analysed.

8.3.4.2 3.1 Decline in resource consumption

In terms of the decline in resource consumption, the most appropriate mode according to the AIC is PDR(10). This finding suggests that the 10 year population decline may be strongly related to the decline in water consumption.

It was found that the rate of population decline over periods of between 5 and 20 years relates to a decline in water consumption, but the 25 year and 30 year population declines may not relate to a decline in water consumption. This is because local water authorities in Japan normally have a 20 year water demand projection for developing their facility plans, and can therefore adjust their businesses to such long-term population decline.

The cause of population decline, geographical factors, and the financial situation may not relate to the decline in water consumption, but the population size, with either no public administrative reforms or a downsizing of the budget, can affect water resource consumption.

8.3.4.2.4 Economic aspect

As an economic aspect, “increase in user charges”, as shown in Table 47, was analysed.

8.3.4.2.4.1 Increase in user charges

The 5 year and 10 year population declines do not relate to an increase in user charges, but population decline over more than 15 years does. In particular, PDR(25), considering the 25-year population decline, is the best model according to indices such as the AIC.

This impact may not relate to public administrative reforms, but municipalities with a low ratio of current expenses to current income, namely a good financial performance, increase user charges. This good financial performance is not a cause, but is probably a result of this impact.

Table 46 Estimation results for decline in resource consumption as the environmental aspect of water and wastewater management

Water supply and waste water management			PDR5		PDR10		PDR15		PDR20		PDR25/30	
		Model sig. (X square test)	0.000		0.000		0.000		0.000		0.000	
		Nagelkerke R Square	0.123		0.133		0.122		0.125		0.107	
		AIC	414.838		412.199		415.047		414.397		418.901	
Category	Variables	Explanation	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance
Demographic change	PDR30	Rate of population decline between 1975 and 2005										
	PDR25	Rate of population decline between 1980 and 2005										
	PDR20	Rate of population decline between 1985 and 2005							-3.085	0.036		
	PDR15	Rate of population decline between 1990 and 2005					-3.735	0.052				
	PDR10	Rate of population decline between 1995 and 2005			-6.738	0.011						
	PDR5	Rate of population decline between 2000 and 2005	-7.365	0.055								
	PopSize	Population in 2005 (thousands)	0.010	0.005	0.011	0.003	0.011	0.005	0.011	0.005	0.008	0.013
	Elderly	Rate of population over 65 years old to total population in 2005										
	ND	Cause of population decline: natural decline (yes=1/No=0)										
	SD_ER	Cause of population decline: higher education or recruiting (yes=1/No=0)										
	SD_AB	Cause of population decline: abolishing branches (yes=1/No=0)										
	SD_AT	Cause of population decline: abolishing public transport (yes=1/No=0)										
	SD_FC	Cause of population decline: finishing large public works(yes=1/No=0)										
	SD_DI	Cause of population decline: main industry decline(yes=1/No=0)										
	Dec_Pat	How population decline happens (1=partial/0=holistic)										
Geographic factors	Area	Areas of municipaliteis (km^2)										
	DIDPop	Ratio of population in the density inhabitat district to total population in 2005 （indicator of										
	HabitableA	Ratio of habitable areas in the areas of municipality in 2006（Indicators of hardness of geography)										
	PrimeIndustry	Ratio of population in primary industry to population between 15 years and 65 years old										
Amount of infrastructure	Schools	Number of schools per area in 2005										
	Housing	Ownership of public dwellings in 2008 (Yes=1/ No=0)										
	Facilities	Number of libraries and comminity houses per area in 2005										
	Parks	Number of parks per area in 2005										
	Tanks	Number of septic tanks per area in 2004										
	Transport	Existing public transport facilities in 2008 (Yes=1/No=0)	-0.834	0.002	-0.899	0.001	-0.893	0.001	-0.905	0.001	-0.814	0.002
	Road	Road length per area in 2005 (km/km2)										
	A-Disaster	Existing anti-disaster facilities in 2008 (Yes=1/No=0)										
Public administratio	re_P.Service	Reform of public administratio services in 2008 (Yes=1/No=0)	-0.669	0.027	-0.684	0.025	-0.680	0.025	-0.707	0.021	-0.609	0.042
	M&A_Facilities	Abolishing public facilities or infrastructure in 2008 (Yes=1/No=0)										
	Contrac-out	Promoting contracting out in 2008 (Yes=1/No=0)										
	Downsize_Finance	Downsizing budget in 2008 (Yes=1/No=0)	0.752	0.002	0.765	0.002	0.746	0.003	0.752	0.002	0.753	0.002
	Re_Salary	Reforms of salary system of municipality officers in 2008 (Yes=1/No=0)										
	e-Gov	Promoting e-government in 2008 (Yes=1/No=0)										
	Not_Enough	Insufficient public administratio reform in 2008 (Yes=1/No=0)										
Financial situation	Reve-Expend	Ratio of general revenue and expenditure balance in 2005										
	Debt-Repay	Ratio of debt repayment in 2005										
Constant			-0.202	0.577	-0.452	0.250	-0.256	0.501	-0.288	0.445	0.234	0.403

Table 47 Estimation results for increase in user charges as the economic aspect of water and wastewater management

Water supply and waste water management			PDR5/10		PDR15		PDR20		PDR25		PDR30	
		Model sig. (X square test)	0.003		0.001		0.001		0.000		0.001	
		Nagelkerke R Square	0.075		0.074		0.078		0.083		0.079	
		AIC	416.872		414.948		414.040		412.768		413.821	
Category	Variables	Explanation	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance
Demographic change	PDR30	Rate of population decline between 1975 and 2005									-2.650	0.006
	PDR25	Rate of population decline between 1980 and 2005							-3.349	0.004		
	PDR20	Rate of population decline between 1985 and 2005					-3.717	0.007				
	PDR15	Rate of population decline between 1990 and 2005			-4.593	0.011						
	PDR10	Rate of population decline between 1995 and 2005										
	PDR5	Rate of population decline between 2000 and 2005										
	PopSize	Population in 2005 (thousands)	-0.008	0.034								
	Elderly	Rate of population over 65 years old to total population in 2005										
	ND	Cause of population decline: natural decline (yes=1/No=0)										
	SD_ER	Cause of population decline: higher education or recruiting (yes=1/No=0)										
	SD_AB	Cause of population decline: abolishing branches (yes=1/No=0)										
	SD_AT	Cause of population decline: abolishing public transport (yes=1/No=0)										
	SD_FC	Cause of population decline: finishing large public works(yes=1/No=0)										
	SD_DI	Cause of population decline: main industry decline(yes=1/No=0)										
	Dec_Pat	How population decline happens (1=partial/0=holistic)										
Geographic factors	Area	Areas of municipaliteis (km^2)										
	DIDPop	Ratio of population in the density inhabitat district to total population in 2005 （indicator of										
	HabitableA	Ratio of habitable areas in the areas of municipality in 2006（Indicators of hardness of geography)										
	PrimeIndustry	Ratio of population in primary industry to population between 15 years and 65 years old										
Amount of infrastructure	Schools	Number of schools per area in 2005										
	Housing	Ownership of public dwellings in 2008 (Yes=1/ No=0)										
	Facilities	Number of libraries and comminity houses per area in 2005										
	Parks	Number of parks per area in 2005	0.506	0.084								
	Tanks	Number of septic tanks per area in 2004										
	Transport	Existing public transport facilities in 2008 (Yes=1/No=0)			-0.514	0.057	-0.524	0.053	-0.530	0.051	-0.520	0.055
	Road	Road length per area in 2005 (km/km2)										
	A-Disaster	Existing anti-disaster facilities in 2008 (Yes=1/No=0)	0.461	0.055	0.416	0.083	0.421	0.079	0.430	0.073	0.431	0.072
Public administratio	re_P.Service	Reform of public administratio services in 2008 (Yes=1/No=0)	0.574	0.057								
	M&A_Facilities	Abolishing public facilities or infrastructure in 2008 (Yes=1/No=0)										
	Contrac-out	Promoting contracting out in 2008 (Yes=1/No=0)										
	Downsize_Finance	Downsizing budget in 2008 (Yes=1/No=0)										
	Re_Salary	Reforms of salary system of municipality officers in 2008 (Yes=1/No=0)										
	e-Gov	Promoting e-government in 2008 (Yes=1/No=0)										
	Not_Enough	Insufficient public administratio reform in 2008 (Yes=1/No=0)										
Financial situation	Reve-Expend	Ratio of general revenue and expenditure balance in 2005	-7.956	0.022	-6.687	0.049	-6.358	0.059	-6.381	0.056	-6.739	0.044
	Debt-Repay	Ratio of debt repayment in 2005										
Constant			-0.571	0.079	-0.802	0.015	-0.858	0.010	-0.877	0.007	-0.781	0.011

8.3.4.3 Roads

This section explains the estimation results for the impact on roads. The response rate in the survey regarding roads is not high, but we managed to collect 316 samples, which is sufficient number for statistical analysis.

8.3.4.3.1 Social aspect

8.3.4.3.1.1 Decline in traffic

As a social aspect, “Decline in traffic”, as shown in Table 48, was analysed.

Table 48 Estimation results for decline in traffic as the social aspect of roads

Road			PDR5/10/15/20/25/30	
		Model sig. (X square test)	0.001	
		Nagelkerke R Square	0.138	
		AIC	226.389	
Category	Variables	Explanation	Coefficients	Probability of significance
Demographic change	PDR30	Rate of population decline between 1975 and 2005		
	PDR25	Rate of population decline between 1980 and 2005		
	PDR20	Rate of population decline between 1985 and 2005		
	PDR15	Rate of population decline between 1990 and 2005		
	PDR10	Rate of population decline between 1995 and 2005		
	PDR5	Rate of population decline between 2000 and 2005		
	PopSize	Population in 2005 (thousands)		
	Elderly	Rate of population over 65 years old to total population in 2005	8.899	0.006
	ND	Cause of population decline: natural decline (yes=1/No=0)		
	SD_ER	Cause of population decline: higher education or recruiting (yes=1/No=0)	1.676	0.052
	SD_AB	Cause of population decline: abolishing branches (yes=1/No=0)		
	SD_AT	Cause of population decline: abolishing public transport (yes=1/No=0)	1.122	0.079
	SD_FC	Cause of population decline: finishing large public works(yes=1/No=0)		
	SD_DI	Cause of population decline: main industry decline(yes=1/No=0)		
	Dec_Pat	How population decline happens (1=partial/0=holistic)		
Geographic factors	Area	Areas of municipaliteis (km^2)	0.002	0.008
	DIDPop	Ratio of population in the density inhabitat district to total population in 2005 （indicator of urban/rural)		
	HabitableA	Ratio of habitable areas in the areas of municipality in 2006（Indicators of hardness of geography)		
	PrimeIndustry	Ratio of population in primary industry to population between 15 years and 65 years old		
Amount of infrastructure	Schools	Number of schools per area in 2005	2.742	0.016
	Housing	Ownership of public dwellings in 2008 (Yes=1/ No=0)		
	Facilities	Number of libraries and comminity houses per area in 2005		
	Parks	Number of parks per area in 2005		
	Tanks	Number of septic tanks per area in 2004		
	Transport	Existing public transport facilities in 2008 (Yes=1/No=0)		
	Road	Road length per area in 2005 (km/km2)		
	A-Disaster	Existing anti-disaster facilities in 2008 (Yes=1/No=0)		
Public administratio	re_P.Service	Reform of public administratio services in 2008 (Yes=1/No=0)		
	M&A_Facilities	Abolishing public facilities or infrastructure in 2008 (Yes=1/No=0)		
	Contrac-out	Promoting contracting out in 2008 (Yes=1/No=0)		
	Downsize_Finance	Downsizing budget in 2008 (Yes=1/No=0)		
	Re_Salary	Reforms of salary system of municipality officers in 2008 (Yes=1/No=0)		
	e-Gov	Promoting e-government in 2008 (Yes=1/No=0)		
	Not_Enough	Insufficient public administratio reform in 2008 (Yes=1/No=0)		
Financial situation	Reve-Expend	Ratio of general revenue and expenditure balance in 2005		
	Debt-Repay	Ratio of debt repayment in 2005		
Constant			-6.706	0.000

According to the estimation results, there is no relationship between the rate of population decline and the decline in traffic. By contrast, the estimated model includes positive coefficients for “Elderly”, “SD_ER”, “SD_AT”, “Area”, and “School”. This finding suggests that the municipalities from which the young migrate to attend higher education or find a job acquire a higher number of elderly people. They may also have a segmented geographical terrain, as implied by the larger number of schools, and without public transport the traffic on roads naturally declines.

8.3.4.3.2 Engineering aspect

As an engineering aspect, “contracting out O&M work”, shown in Table 49, and “decline in the level of maintenance”, shown in Table 50, were analysed.

8.3.4.3.2.1 Contracting out O&M

No model considering the rate of population decline on “contracting out O&M” seemed to be statistically significant. The model considered most valid according to the AIC includes negative coefficients for “ND”, “Schools”, “M&A_Facilities”, and “Re_Salary” and positive coefficients for “Area” and “Tanks”. This result suggests that contracting out road maintenance work can be seen in municipalities with larger areas, smaller numbers of schools, and many septic tanks (i.e. those located in rural areas) that have experienced no merging and closure of public facilities and infrastructure, or reviewed the salaries of public officers.

8.3.4.3.2.2 Decline in the level of maintenance

The estimation results suggest that there is no relationship between the rate of population decline and the decline in the level of maintenance. By contrast, negative relationships could be found between the declines in the level of maintenance and “Popsize”, “Elderly”, “Dec_Pat”, and “Schools”, as well as positive relationships between the decline in the level of maintenance and “SD_DI”, “SD_FC”, “HabitableA”, “Parks”, “A-Disaster”, and “re_P.Service”.

These results imply that the review of their policies by municipalities with smaller but younger populations, with fewer schools but many parks and anti-disaster facilities, which once experienced industrial decline, will lead to a decline in the level of maintenance.

Table 49 Estimation results for contracting out O&M work as the engineering aspect of the roads sector

Road			PDR5/10/15/20/30		PDR25	
		Model sig. (X square test)	0.004		0.003	
		Nagelkerke R Square	0.156		0.202	
		AIC	113.933		113.335	
Category	Variables	Explanation	Coefficients	Probability of significance	Coefficients	Probability of significance
Demographic change	PDR30	Rate of population decline between 1975 and 2005				
	PDR25	Rate of population decline between 1980 and 2005				
	PDR20	Rate of population decline between 1985 and 2005				
	PDR15	Rate of population decline between 1990 and 2005				
	PDR10	Rate of population decline between 1995 and 2005				
	PDR5	Rate of population decline between 2000 and 2005				
	PopSize	Population in 2005 (thousands)				
	Elderly	Rate of population over 65 years old to total population in 2005				
	ND	Cause of population decline: natural decline (yes=1/No=0)	-3.242	0.016	-6.475	0.015
	SD_ER	Cause of population decline: higher education or recruiting (yes=1/No=0)				
	SD_AB	Cause of population decline: abolishing branches (yes=1/No=0)				
	SD_AT	Cause of population decline: abolishing public transport (yes=1/No=0)				
	SD_FC	Cause of population decline: finishing large public works(yes=1/No=0)				
	SD_DI	Cause of population decline: main industry decline(yes=1/No=0)				
	Dec_Pat	How population decline happens (1=partial/0=holistic)				
Geographic factors	Area	Areas of municipaliteis (km^2)	0.002	0.006	0.002	0.019
	DIDPop	Ratio of population in the density inhabitat district to total population in 2005 （indicator of urban/rural)				
	HabitableA	Ratio of habitable areas in the areas of municipality in 2006（Indicators of hardness of geography)				
	PrimeIndustry	Ratio of population in primary industry to population between 15 years and 65 years old				
Amount of infrastructure	Schools	Number of schools per area in 2005			-8.846	0.058
	Housing	Ownership of public dwellings in 2008 (Yes=1/ No=0)				
	Facilities	Number of libraries and comminity houses per area in 2005				
	Parks	Number of parks per area in 2005				
	Tanks	Number of septic tanks per area in 2004			18.487	0.083
	Transport	Existing public transport facilities in 2008 (Yes=1/No=0)				
	Road	Road length per area in 2005 (km/km2)				
	A-Disaster	Existing anti-disaster facilities in 2008 (Yes=1/No=0)				
Public administratio	re_P.Service	Reform of public administratio services in 2008 (Yes=1/No=0)				
	M&A_Facilities	Abolishing public facilities or infrastructure in 2008 (Yes=1/No=0)	-1.117	0.050	-1.140	0.046
	Contrac-out	Promoting contracting out in 2008 (Yes=1/No=0)				
	Downsize_Finance	Downsizing budget in 2008 (Yes=1/No=0)				
	Re_Salary	Reforms of salary system of municipality officers in 2008 (Yes=1/No=0)	-1.732	0.030	-1.923	0.021
	e-Gov	Promoting e-government in 2008 (Yes=1/No=0)				
	Not_Enough	Insufficient public administratio reform in 2008 (Yes=1/No=0)				
Financial situation	Reve-Expend	Ratio of general revenue and expenditure balance in 2005				
	Debt-Repay	Ratio of debt repayment in 2005				
Constant			2.018	0.188	5.744	0.050

Table 50 Estimation results for the decline in the level of maintenance as the engineering aspect of the roads sector

Road			PDR5/10/15/20/25/30	
		Model sig. (X square test)	0.000	
		Nagelkerke R Square	0.223	
		AIC	294.157	
Category	Variables	Explanation	Coefficients	pability of significa
Demographic change	PDR30	Rate of population decline between 1975 and 2005		
	PDR25	Rate of population decline between 1980 and 2005		
	PDR20	Rate of population decline between 1985 and 2005		
	PDR15	Rate of population decline between 1990 and 2005		
	PDR10	Rate of population decline between 1995 and 2005		
	PDR5	Rate of population decline between 2000 and 2005		
	PopSize	Population in 2005 (thousands)	-0.013	0.060
	Elderly	Rate of population over 65 years old to total population in 2005	-8.378	0.011
	ND	Cause of population decline: natural decline (yes=1/No=0)		
	SD_ER	Cause of population decline: higher education or recruiting (yes=1/No=0)		
	SD_AB	Cause of population decline: abolishing branches (yes=1/No=0)		
	SD_AT	Cause of population decline: abolishing public transport (yes=1/No=0)		
	SD_FC	Cause of population decline: finishing large public works(yes=1/No=0)	1.241	0.064
	SD_DI	Cause of population decline: main industry decline(yes=1/No=0)	0.727	0.020
	Dec_Pat	How population decline happens (1=partial/0=holistic)	-0.924	0.030
Geographic factors	Area	Areas of municipaliteis (km^2)		
	DIDPop	Ratio of population in the density inhabitat district to total population in 2005 （indicator of urban/rural)		
	HabitableA	Ratio of habitable areas in the areas of municipality in 2006（Indicators of hardness of geography)	2.644	0.019
	PrimeIndustry	Ratio of population in primary industry to population between 15 years and 65 years old		
Amount of infrastructure	Schools	Number of schools per area in 2005	-3.226	0.082
	Housing	Ownership of public dwellings in 2008 (Yes=1/ No=0)		
	Facilities	Number of libraries and comminity houses per area in 2005		
	Parks	Number of parks per area in 2005	3.089	0.080
	Tanks	Number of septic tanks per area in 2004		
	Transport	Existing public transport facilities in 2008 (Yes=1/No=0)		
	Road	Road length per area in 2005 (km/km2)		
	A-Disaster	Existing anti-disaster facilities in 2008 (Yes=1/No=0)	0.793	0.010
Public administratio	re_P.Service	Reform of public administratio services in 2008 (Yes=1/No=0)	0.755	0.045
	M&A_Facilities	Abolishing public facilities or infrastructure in 2008 (Yes=1/No=0)		
	Contrac-out	Promoting contracting out in 2008 (Yes=1/No=0)		
	Downsize_Finance	Downsizing budget in 2008 (Yes=1/No=0)		
	Re_Salary	Reforms of salary system of municipality officers in 2008 (Yes=1/No=0)		
	e-Gov	Promoting e-government in 2008 (Yes=1/No=0)		
	Not_Enough	Insufficient public administratio reform in 2008 (Yes=1/No=0)		
Financial situation	Reve-Expend	Ratio of general revenue and expenditure balance in 2005		
	Debt-Repay	Ratio of debt repayment in 2005		
Constant			0.949	0.424

8.3.4.3.3 Environmental aspect

As an environmental aspect, “decline in pollution”, shown in Table 51, was analysed.

In terms of the decline in pollution such as noise, vibration, and air pollution, only PDR(20), which considers the 20 year population decline, emerged as statistically significant, however, PDR(20) has a bigger AIC than the other models without the variable of population decline, which means that it is not a valid model.

The most appropriate model includes positive coefficients for “Schools” and “Downsize_Finance” and negative coefficients for “Tanks” and “Road”. Thus, municipalities with many schools, short road distances, and fewer septic tanks, namely urban municipalities, may experience a decline in pollution on the roads.

8.3.4.3.4 Economic aspect

As an economic aspect, “decline in tax revenue”, shown in Table 52, was analysed.

The decline in tax revenue could relate statistically to the 10 year (PDR(10)) or 15 year (PDR(15)) population decline. PDR(10) has a smaller AIC, which means that it is a better model than PDR(15) from a statistical perspective.

PDR(10) also includes positive coefficients for “SD_AT” and “re_P.Service”, but a negative coefficient for “Schools”. Accordingly, it is possible that a municipality with relatively fewer schools that has experienced population decline and so closed down public transport, faces a decline in the revenue of tax from cars, and this will result in a review of the public administration service.

Table 51 Estimation results for decline in pollution as the environmental aspect of the roads sector

Road			PDR5/PDR10/PDR15/PDR30		PDR20		PDR25	
		Model sig. (X square test)	0.000		0.000		0.000	
		Nagelkerke R Square	0.373		0.372		0.308	
		AIC	62.460		62.500		65.060	
Category	Variables	Explanation	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance
Demographic change	PDR30	Rate of population decline between 1975 and 2005						
	PDR25	Rate of population decline between 1980 and 2005						
	PDR20	Rate of population decline between 1985 and 2005			-9.193	0.038		
	PDR15	Rate of population decline between 1990 and 2005						
	PDR10	Rate of population decline between 1995 and 2005						
	PDR5	Rate of population decline between 2000 and 2005						
	PopSize	Population in 2005 (thousands)						
	Elderly	Rate of population over 65 years old to total population in 2005						
	ND	Cause of population decline: natural decline (yes=1/No=0)						
	SD_ER	Cause of population decline: higher education or recruiting (yes=1/No=0)						
	SD_AB	Cause of population decline: abolishing branches (yes=1/No=0)						
	SD_AT	Cause of population decline: abolishing public transport (yes=1/No=0)						
	SD_FC	Cause of population decline: finishing large public works(yes=1/No=0)						
	SD_DI	Cause of population decline: main industry decline(yes=1/No=0)						
	Dec_Pat	How population decline happens (1=partial/0=holistic)						
Geographic factors	Area	Areas of municipaliteis (km^2)						
	DIDPop	Ratio of population in the density inhabitat district to total population in 2005 （indicator of urban/rural)						
	HabitableA	Ratio of habitable areas in the areas of municipality in 2006（Indicators of hardness of geography)						
	PrimeIndustry	Ratio of population in primary industry to population between 15 years and 65 years old						
Amount of infrastructure	Schools	Number of schools per area in 2005	16.718	0.015	8.488	0.028	6.616	0.086
	Housing	Ownership of public dwellings in 2008 (Yes=1/ No=0)						
	Facilities	Number of libraries and comminity houses per area in 2005						
	Parks	Number of parks per area in 2005						
	Tanks	Number of septic tanks per area in 2004	-73.699	0.080				
	Transport	Existing public transport facilities in 2008 (Yes=1/No=0)						
	Road	Road length per area in 2005 (km/km2)	-1.303	0.009	-1.250	0.019	-1.333	0.009
	A-Disaster	Existing anti-disaster facilities in 2008 (Yes=1/No=0)						
Public administratio	re_P.Service	Reform of public administratio services in 2008 (Yes=1/No=0)						
	M&A_Facilities	Abolishing public facilities or infrastructure in 2008 (Yes=1/No=0)						
	Contrac-out	Promoting contracting out in 2008 (Yes=1/No=0)						
	Downsize_Finance	Downsizing budget in 2008 (Yes=1/No=0)	3.935	0.049	3.376	0.036	3.350	0.027
	Re_Salary	Reforms of salary system of municipality officers in 2008 (Yes=1/No=0)						
	e-Gov	Promoting e-government in 2008 (Yes=1/No=0)						
	Not_Enough	Insufficient public administratio reform in 2008 (Yes=1/No=0)						
Financial situation	Reve-Expend	Ratio of general revenue and expenditure balance in 2005						
	Debt-Repay	Ratio of debt repayment in 2005						
Constant			-4.408	0.023	-6.754	0.001	-4.280	0.006

Table 52 Estimation results for decline in tax revenue as the economic aspect of the roads sector

Road			PDR5/PDR20/PDR25/PDR30		PDR10		PDR15	
		Model sig. (X square test)	0.000		0.000		0.000	
		Nagelkerke R Square	0.233		0.235		0.228	
		AIC	200.1		199.700		200.900	
Category	Variables	Explanation	Coefficients	Probability of significance	Coefficients	Probability of significance	Coefficients	Probability of significance
Demographic change	PDR30	Rate of population decline between 1975 and 2005						
	PDR25	Rate of population decline between 1980 and 2005						
	PDR20	Rate of population decline between 1985 and 2005						
	PDR15	Rate of population decline between 1990 and 2005					-5.977	0.037
	PDR10	Rate of population decline between 1995 and 2005			-9.361	0.020		
	PDR5	Rate of population decline between 2000 and 2005						
	PopSize	Population in 2005 (thousands)						
	Elderly	Rate of population over 65 years old to total population in 2005	8.6161	0.007				
	ND	Cause of population decline: natural decline (yes=1/No=0)						
	SD_ER	Cause of population decline: higher education or recruiting (yes=1/No=0)						
	SD_AB	Cause of population decline: abolishing branches (yes=1/No=0)						
	SD_AT	Cause of population decline: abolishing public transport (yes=1/No=0)	1.5647	0.020	1.426	0.034	1.426	0.033
	SD_FC	Cause of population decline: finishing large public works(yes=1/No=0)						
	SD_DI	Cause of population decline: main industry decline(yes=1/No=0)						
	Dec_Pat	How population decline happens (1=partial/0=holistic)						
Geographic factors	Area	Areas of municipaliteis (km^2)						
	DIDPop	Ratio of population in the density inhabitat district to total population in 2005 （indicator of urban/rural)						
	HabitableA	Ratio of habitable areas in the areas of municipality in 2006（Indicators of hardness of geography)						
	PrimeIndustry	Ratio of population in primary industry to population between 15 years and 65 years old						
Amount of infrastructure	Schools	Number of schools per area in 2005	-6.2272	0.011	-6.613	0.023	-6.793	0.019
	Housing	Ownership of public dwellings in 2008 (Yes=1/ No=0)	-6.2257	0.024				
	Facilities	Number of libraries and comminity houses per area in 2005						
	Parks	Number of parks per area in 2005						
	Tanks	Number of septic tanks per area in 2004						
	Transport	Existing public transport facilities in 2008 (Yes=1/No=0)						
	Road	Road length per area in 2005 (km/km2)						
	A-Disaster	Existing anti-disaster facilities in 2008 (Yes=1/No=0)						
Public administratio	re_P.Service	Reform of public administratio services in 2008 (Yes=1/No=0)	1.8143	0.007	1.312	0.027	1.307	0.028
	M&A_Facilities	Abolishing public facilities or infrastructure in 2008 (Yes=1/No=0)						
	Contrac-out	Promoting contracting out in 2008 (Yes=1/No=0)						
	Downsize_Finance	Downsizing budget in 2008 (Yes=1/No=0)						
	Re_Salary	Reforms of salary system of municipality officers in 2008 (Yes=1/No=0)						
	e-Gov	Promoting e-government in 2008 (Yes=1/No=0)						
	Not_Enough	Insufficient public administratio reform in 2008 (Yes=1/No=0)						
Financial situation	Reve-Expend	Ratio of general revenue and expenditure balance in 2005						
	Debt-Repay	Ratio of debt repayment in 2005						
Constant			0.8229	0.780	-2.595	0.003	-2.393	0.005

8.4 Discussion

In this section, we have highlighted what we found to be the key variables in order to perform a comparison of the impact of population decline on infrastructure management among the four aspects of sustainability, the differences in this impact between the types of infrastructure, the changes in the probability that a particular impact will occur, and ways to assess the effectiveness of policy.

8.4.1 Population decline and its impact

The comparison of the relationship between the impact and population decline among the aspects of infrastructure sustainability and among the three types of infrastructure is discussed in this section.

Table 53, Table 54, and Table 55 show a combination of the impacts and the different periods of population decline. The appearances of the relationships between the impacts, considered from the four aspects of infrastructure sustainability, and the population decline, differ depending on infrastructure type. In particular, in the economic aspects, the relationship between the period of population decline and impact is different between the infrastructure types, because the public facilities and roads are managed using the general budget from the tax revenue supported by the central government, but water and waste water management facilities are managed through user charges and limited financial support from the general municipality budgets. This difference in financial resources appears to result in the differences in their relationships.

This varied appearance suggests the complexity of recognising trends in the impacts of population decline on infrastructure management, and requires researchers to conduct a comprehensive and well-planned study on this topic. Unfortunately, a general trend in the four aspects of infrastructure sustainability and the period of population decline cannot be seen.

Table 53 Relationships between population decline and the impact on public facilities, from the four aspects

Aspects	Impacts	PDR5	PDR10	PDR15	PDR20	PDR25	PDR30
Social	Decline in number of users	✓	✓	✓	✓	✓	✓
	Merging and abolishing facilities		✓		✓	✓	
Engineering	Countracting out maintenance works						
	Decline in the maintenance level		✓	✓			
Environment	Decline in energy and water		✓	✓	✓	✓	
Economic	Increase in user charges						

Table 54 Relationships between population decline and the impact on water infrastructure, from the four aspects

Aspects	Impacts	PDR5	PDR10	PDR15	PDR20	PDR25	PDR30
Social	Merging and abolishing facilities						
Engineering	Contracting out maintenance works				✓		
Environment	Decline in water resources	✓	✓	✓	✓		
Economic	Increase in user charges			✓	✓	✓	✓

Table 55 Relationships between population decline and the impacts on the road infrastructure, from the four aspects

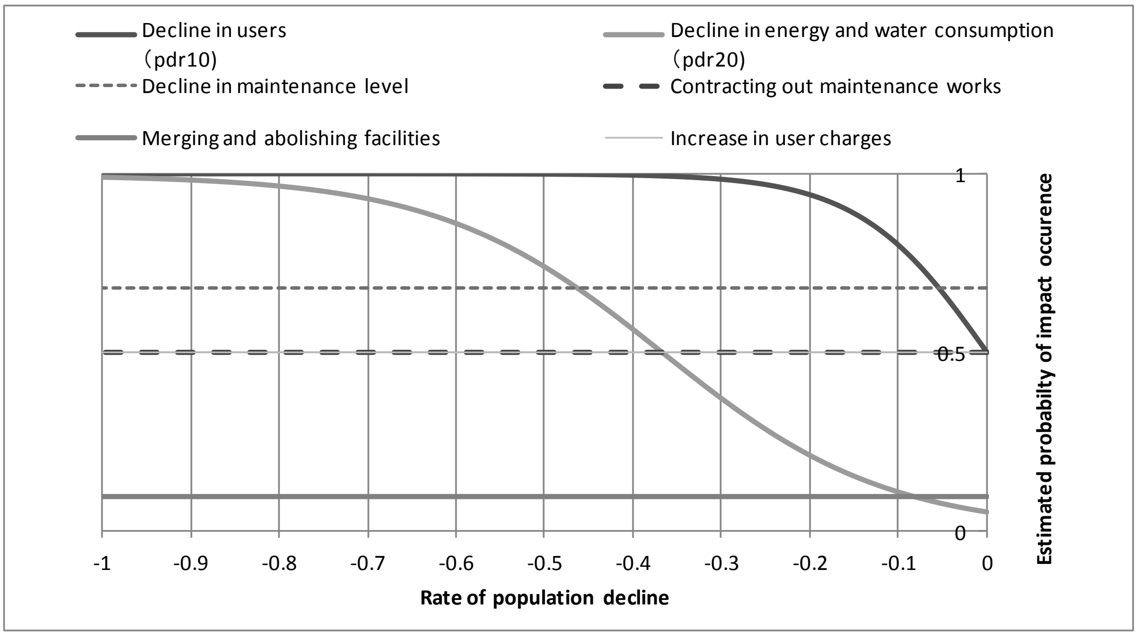
Aspects	Impacts	PDR5	PDR10	PDR15	PDR20	PDR25	PDR30
Social	Decline in road traffic						
Engineering	Decline in maintenance level						
	Contracting out maintenance works						
Environment	Decline in pollution such as noise, air pollution and vibration				✓		
Economic	Decline in tax revenue		✓	✓			

8.4.2 PROBABILITY OF THE IMPACTS OCCURRING

This subsection discusses the relationship between the rate of population decline and the estimated probability of an impact on the four aspects of infrastructure sustainability in the best models for the three types of infrastructure.

The logistic regression analysis used in this study can use binary data as its explanatory variable, but it can be considered as logit, the odds ratio of the event in the model. The logit takes a number between 0 and 1 and is shaped as an S-style curve. Once the best model has been identified, we can use it for estimation of the odds ratio. The following graphs on the three types of infrastructure show the estimated probability of an impact occurring, from the four aspects of infrastructure sustainability. Estimated parameters for the analysis are fixed using the data from 2005, only the rate of population decline is allowed to move whereas the other explanatory variables are fixed and thus they keep the same conditions. This means that the graphs can show the pure effect on the change in probability by population decline. Note that this time the rate of population decline is shown on the x axis but the period of population decline is dependent on the aspect. This means that the timing of the occurrence of the impact is the same, but the period from the timing of the impact occurring should be retroactive in each case. Note also that the original analysis estimated the effect over different numbers of years, but only the rate of decline of the population for the most appropriate period for the estimation is employed in these graphs.

In terms of public facilities, only two impacts, “decline in users” and “decline in energy and water consumption”, are related to population decline shown in Figure 91. A decline in users will probably occur in more than 50% of municipalities when they experience only a 1% population decline over 10 years. By contrast, a decline in energy and water consumption will occur in more than 50% of municipalities when the rate of population decline exceeds 35% over 20 years.

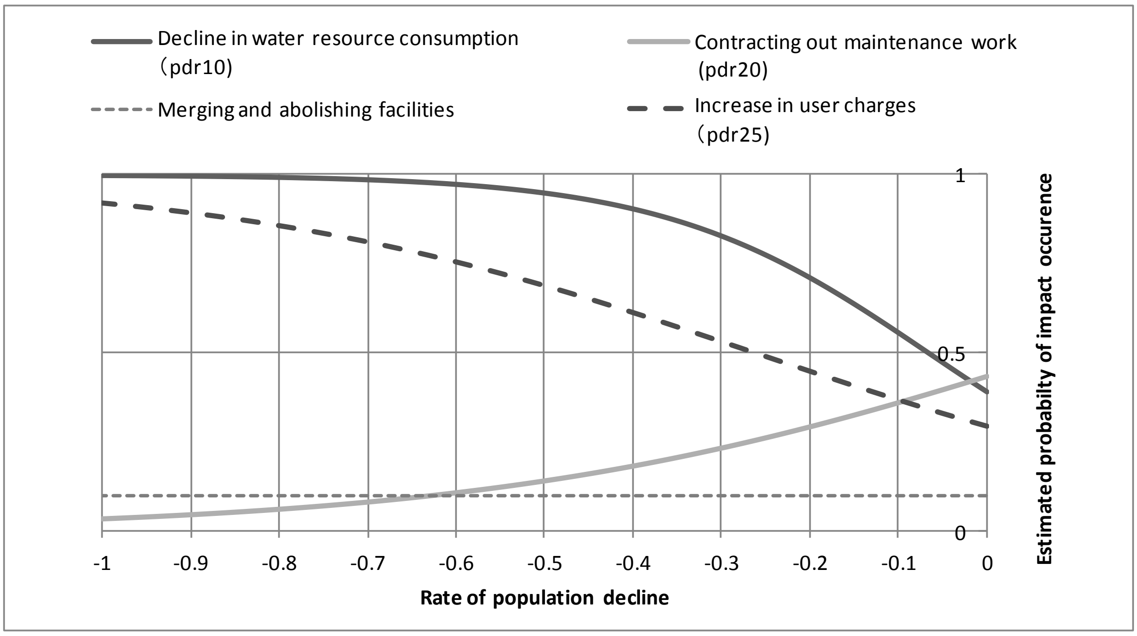


Note: Constant lines in the graph suggest that the impacts illustrated by the lines may have no relation to any population decline tested in this study.

Figure 91 Relationship between the rate of population decline and the estimated probability of an impact occurring for the four aspects of infrastructure sustainability in the best models for public facilities

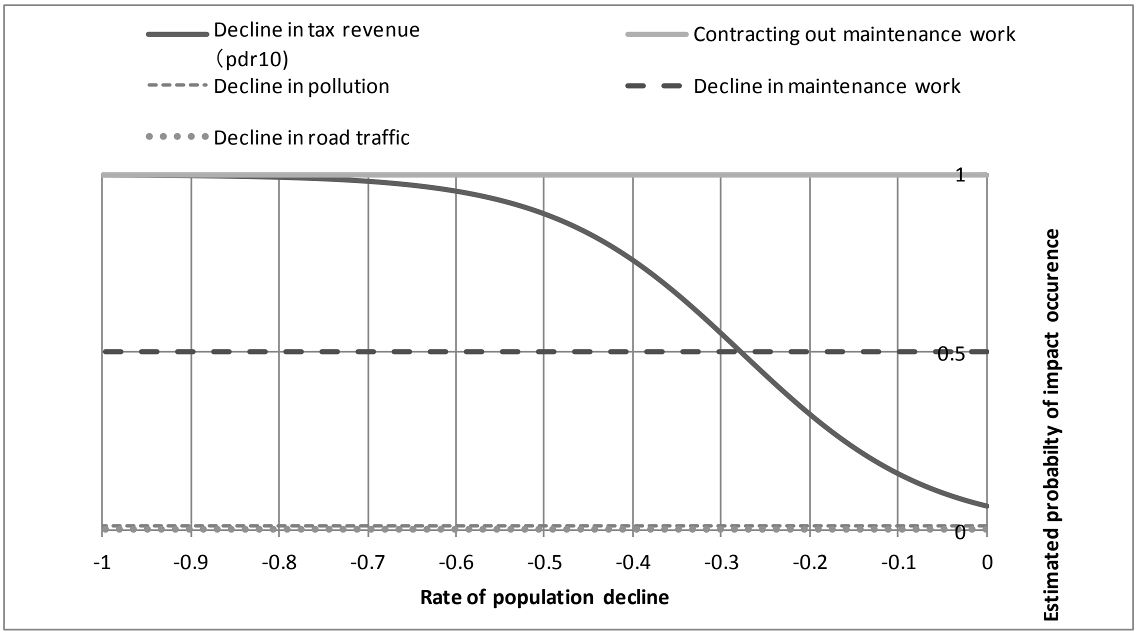
In the water sector shown in Figure 92, mergers and closures in water infrastructure, a social aspect, is not related to the population decline, but other impacts are. The decline in water resource consumption, an environment aspect, will be observed in more than 50% of municipalities that experience more than a 5% decrease in population over 10 years, and almost all municipalities will experience the impact when the rate of population decline exceeds 70%. Similarly, more than 50% of municipalities will experience an increase in user charges when a 25% decrease in population takes place over 25 years. Conversely, the estimated probability of the occurrence of contracting out maintenance work will decline in accordance with the population decline. The reason for this may be that the size of a municipality with a population decline is normally smaller. This point should be examined in subsequent research.

In terms of the roads sector shown in Figure 93, only the economic aspect is related to the population decline in the best model, so the probabilities of the other impacts are stable in the graph. By contrast, the estimated probability of impact occurrence for the economic aspect will be over 50% if the rate of population decline exceeds 25% over 10 years.



Note: Constant lines in the graph suggest that the impacts illustrated by the lines may have no relation to any population decline tested in this study.

Figure 92 Relationship between the rate of population decline and the estimated probability of an impact occurring for the four aspects of infrastructure sustainability in the best models for water supply and wastewater management



Note: Constant lines in the graph suggest that the impacts illustrated by the lines may have no relation to any population decline tested in this study.

Figure 93 Relationship between the rate of population decline and the estimated probability of an impact occurring for the four aspects of infrastructure sustainability in the best models in road infrastructure

8.4.3 Appraisal of the Sustainability and Effects of Policies

In order to assess the sustainability of the infrastructure in municipalities against the risk of impacts occurring, the inter-temporal balance between risks should be discussed. In this subsection, therefore, the value of risks, using data from the city of Hakodate in Hokkaido, is calculated, and the effects of policy reform on either the general administration of local government or infrastructure management is assessed. The intention of the discussion in this section is to illustrate how this analysis can be applied to infrastructure management by infrastructure managers in municipalities. There is thus no specific reason to select the city of Hakodate.

As described in the methodology section, a two-step approach is taken for this analysis. First, the prediction for 2010 is calculated by changing the population in 2005 to the population in 2010. The data in 2010 is from the population census in Japan conducted in 2010 (Ministry of Internal Affairs and Telecommunication 2011). Second, some policy variables are changed as policy countermeasures. The timings relate to 2008, which is the year in which data was collected for the geography and asset values of the infrastructure, 2005 for the national census data, and 2010 for the latest population data.

Among the explanatory variables in this study, the amount of infrastructure, the situation of local governmental policy reform, and the financial conditions in the municipality are the variables that can be controlled from a policy perspective.

The original assessment results for infrastructure sustainability using the identified model are illustrated in Figure 94 to Figure 96. The axes of three aspects, social, engineering, and economy, show the negative impacts (i.e. a larger number means a worse situation), while the axis of the environmental aspect shows a positive impact (a larger number means a better situation). Accordingly, the distorted diamond below is the best shape for the graph in this case.

For public facilities, the estimated probability in 2005 and 2010 is distorted in both the social aspect (mergers and closures) and the engineering aspect (decline in the level of maintenance work), so that the distortion of the shape is not desirable. For such a situation, “selling public housing” and “downsizing budget size” can be considered as possible policy reforms.

Between 2005 and 2010, the population decline led to a slightly worsening in the social aspect of infrastructure sustainability, although the other aspects remained in almost the same situations. This means that the infrastructure sustainability in the city of Hakodate was not in the most desirable state, but that the status quo was maintained and that the situation could be considered sustainable in the sense of not becoming worse. If the assumed policy reforms, such as selling public housing and downsizing the budget size, are introduced, the sustainability of infrastructure management in the city of Hakodate might improve due to reduced energy and water charges.

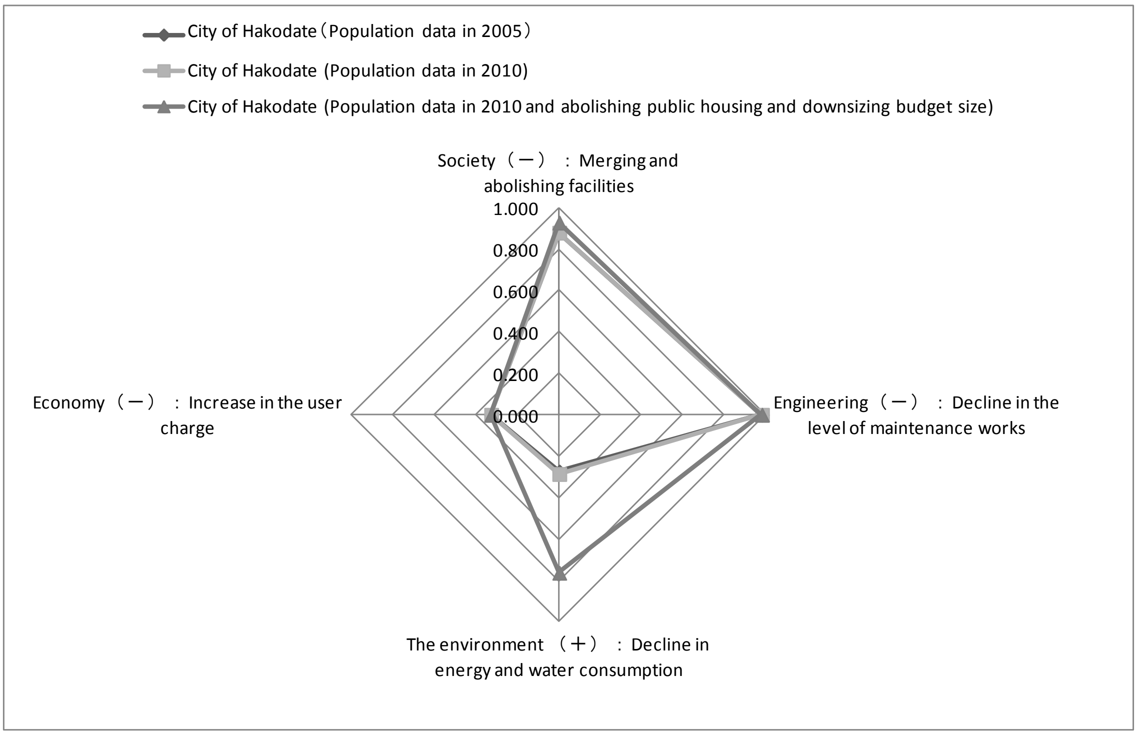


Figure 94 Example of the change in balance among the four aspects of infrastructure sustainability in public facilities in the city of Hakodate in Hokkaido

In terms of water supply and wastewater management, the probability of a positive environmental impact is originally the highest, and the probability of a negative engineering impact is the lowest. This finding suggests that the level of sustainability in those two aspects is relatively higher than in the other aspects; in other words, there is a higher probability of negative impacts occurring in social and economic aspects.

In the city of Hakodate, the population change between 2005 and 2010 did not influence the sustainability of water supply and wastewater management infrastructure significantly, but it worsened the economic aspect slightly, and could have improved the engineering aspect a little. By introducing a "downsizing budget" in 2010 in the city of Hakodate, the score for the environmental aspect could be improved but the other aspects would not be affected. This means that the sustainability of the water supply and wastewater management can be improved overall.

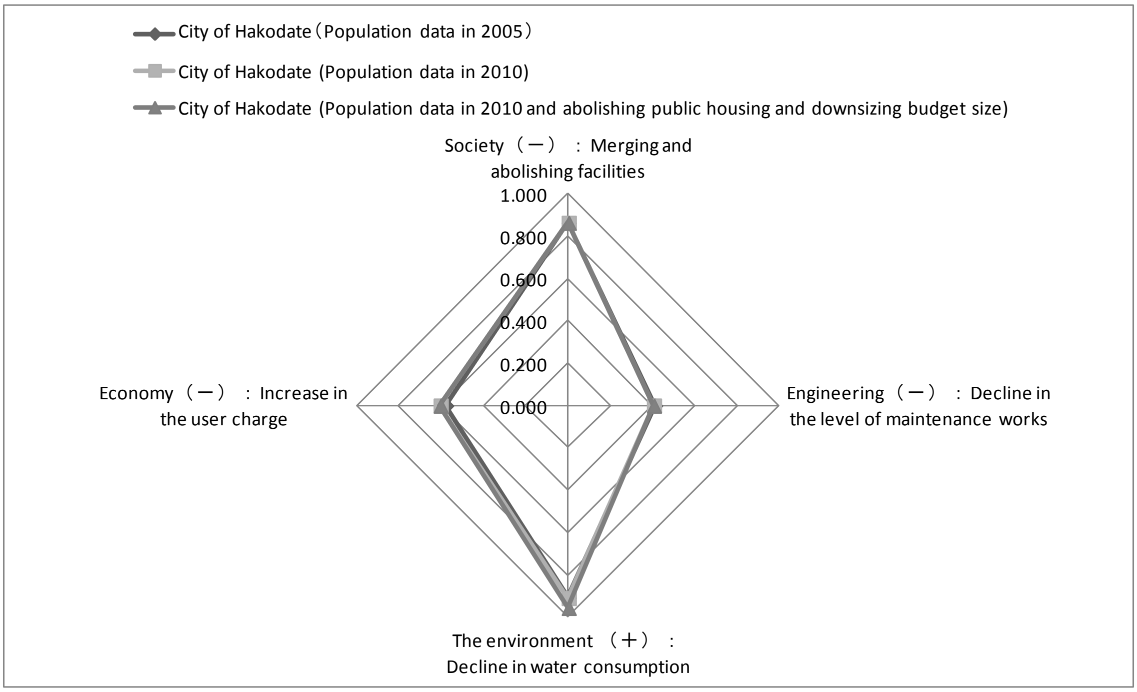


Figure 95 Example of the change in balance among the four aspects of infrastructure sustainability in water infrastructure in the city of Hakodate in Hokkaido

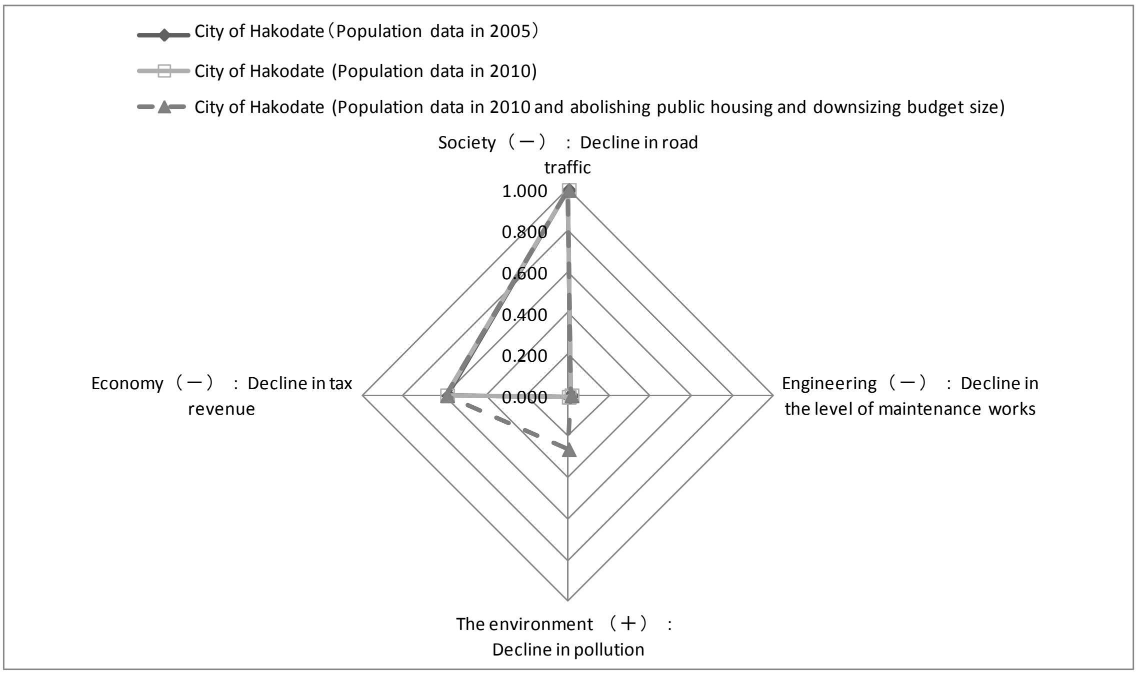


Figure 96 Example of the change in balance among the four aspects of infrastructure sustainability in road infrastructure in the city of Hakodate in Hokkaido

In terms of roads, the probability that an impact occurs in the social aspect, through a decline in traffic on the roads, is almost 100%, while the probability of an impact occurring in the engineering aspect, namely "decline in the maintenance level", or the environmental aspect, "decline in pollution", is effectively 0%, and the probability of an economic impact, "decline in tax revenue", is around 60%. In 2010, the population of the city of Hakodate had declined by 4.8% compared with the population in 2005. Even from an economic aspect, which is significantly related to the rate of population decline, the probability of the occurrence of an impact in 2010 had not noticeably changed since 2005. By contrast, the decline in budget size enabled a reduction of 30% of the impact to be achieved in the environmental aspect.

In this way, when a policy reform that influences infrastructure sustainability is discussed, as long as the explanatory variables that relate to the policy are included in the model used, an impact analysis of the effect of introducing the policy can also be conducted by changing the related explanatory variables.

8.5 Concluding remarks

This study developed a method for statistically analysing the relationship between the impacts of the four aspects of infrastructure sustainability and population decline using municipality-level data. This enables researchers and infrastructure managers at the national level to ascertain the impact of population decline on infrastructure management with a higher resolution than previously. In concrete terms, the study used a binary logistic regression model to analyse the relationship between impacts from the four aspects of infrastructure sustainability using data collected through a structured questionnaire undertaken in depopulating municipalities, the rate of population decline, and other statistics from the municipalities in the sample. The analysis resulted in profiles of the types of depopulating areas likely to suffer from the impact of population decline, while the degree of probability of this happening can be estimated from the models identified. An assessment of proposed policy reforms that could mitigate the impact of population decline can be undertaken utilising the statistically significant explanatory variables.

Based on this analysis, we found that all the impacts reported in previous research in depopulating areas are not necessarily or statistically significant direct impacts of population decline. In addition, it was found that a specific period of population decline will probably affect infrastructure sustainability. The study also shows, by considering explanatory variables other than demographic and geographic factors, that the impact observed in depopulating municipalities may come from the history of infrastructure development and the general policies of municipalities.

The analytical approach in this study only focuses on the independent relationship between the explanatory variables and the occurrence of the impacts, assuming a simple relationship between the impacts and their potential factors. Of course, the actual potential relationship between causes and effects is complicated, and latent factors that this study cannot consider may influence the relationships identified. In order to discuss this point, another analytical method, such as structural equation modelling, should be introduced for the same data.

Five other points should also be considered before concluding this discussion. First, this study considers the relationship between population decline and impact; however, some infrastructure types are also affected by changes in the number of households. If the variables of population decline, PDR, could substitute for the variables of household decline, HDR, it would be possible to conduct the same type of analysis.

Second, municipality-level data was used in this study because it can be easily collected. The impacts of population decline on infrastructure are, however, often reported at a micro level. Perforation is a typical term describing how to show the impacts. In order to discuss this phenomenon at an appropriate level, geographical data, such as mesh data, should also be used in further research. Of course, a spatial binary regression model should be applied for analysing the spatial data, but the difficulty is that they have the same resolution.

Third, this study discusses the estimated probability of the occurrence of an impact on infrastructure sustainability, but the data of the dependent variables are from a field survey rather than from statistics. Of course, data from a survey can reflect the actual occurrence of the impacts, but it costs money to collect this data regularly. Accordingly, it is expected that open source statistics that represent the impact of population decline on infrastructure management should be used for the analysis. Management accounting for infrastructure management is a potential source of such data.

The abovementioned point easily leads to the research idea of developing sustainable development indicators (SDIs) for infrastructure. The model identified in this study can be considered a preliminary version of SDIs on infrastructure management. The discussion throughout this paper suggests that the character of this topic is pass-dependent, and if we want to manage the impact of population decline on infrastructure management from a sustainability perspective, we should develop a monitoring method. SDIs on infrastructure are one feasible research idea for accomplishing this.

Finally, as described above, the history of infrastructure development can significantly affect the impact of population decline on infrastructure, although there is very little research on the relationship between policy history and the occurrence of problems. Research should consider this point as well as the points mentioned above.

In conclusion, this study could be extended to discuss the impact of population decline on infrastructure management from a sustainability perspective, not only qualitatively but also quantitatively. This is a significant advance in the history of the discussion on this topic. This research topic is still at a very early stage. The research tasks mentioned above are expected to be conducted by future researchers.

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CHAPTER 9: ANALYSIS 2: PREFERENCES FOR DEVELOPMENT OPTIONS IN DEPOPULATING AND NON-DEPOPULATING AREAS: A CHOICE EXPERIMENT APPROACH[8]

8 Part of this chapter has been already published as Uemura, T. (2011) An Estimation of Marginal Willingness to Pay by Choice Modeling on the Timing and Service Level of Sustainable Water Supply and Waste Water Management Infrastructure in Population Decline, Journal of Public Utility Economics, 63(2), 31-40.

9.1 INTRODUCTION

According to the literature review chapter, the balance in the sustainability of infrastructure development and management has not been fully discussed in the previous studies, although some work has been carried out on the balance between various aspects of infrastructure outside the context of sustainability. For example, “the rate of special purpose tax”, “the range of garbage”, “the number of houses”, “the existence of a drinking water source” and “the distance from the house of the respondent” were evaluated simultaneously in a discussion of the choice of location for a solid waste management plant (Sasao, 2004). Another paper discussed airport infrastructure development by simultaneously evaluating “access time”, “the number of take-offs and landings”, “the number of households needing noise prevention”, “the area of nature destruction” and the “cost of construction” (Tanimoto and Hagishima, 2004). Other work focused on the case for the choice of mode of transportation including mono-rail development, taking into consideration “entrainment time”, “access time for transport”, “frequency”, “fare” and “negative impacts on the environment” (Chin, Sakata and Hashimoto, 2006).

These previous pieces of research did not consider the timing of infrastructure development, thus tacitly suggesting present infrastructure development. Intergenerational equity is, however, necessary for the discussion of infrastructure sustainability. An evaluation of the timing of infrastructure development and management – in other words new construction, maintenance works and replacement – is of considerable importance; however, to the best of our knowledge, no research has so far evaluated timing or other aspects of infrastructure development.

This study aims to discuss the balance and priority of different aspects of infrastructure sustainability, namely “society”, “engineering”, “environment”, “economy” and “timing of development and management”, within public preferences for infrastructure development and management options. We use a choice experiment approach for this purpose.

Choice experiments (CE) are the survey-based stated preference methods used for the monetary valuation of non-market goods that are multidimensional in nature (Louviere et al., 2000). In a CE, the good to be valued is described as a function of its attributes (one of which is a price or cost attribute), varying at different levels. Respondents are presented with different combinations of these attributes and asked to choose their most preferred combination. Respondent valuations (or willingness to pay) for the goods and its attributes are revealed by subsequent analysis of their choices. Choice experiments are therefore a good way to evaluate preferences for different aspects of infrastructure development and management policies. In our experiment, each policy attribute reflects one of the four sustainability aspects of interest (society, engineering, environment and economy).

The timing of development and maintenance is also included as an attribute of the choice experiment, in the same way as the other elements of the evaluation. In a related study, Viscusi, Huber and Bell (2008) used a choice experiment approach, to evaluate preferences for water quality improvements, where timing of the improvement was an attribute of the choice. The marginal willingness to pay (MWTP) for the various sustainability aspects within each infrastructure type was also estimated in order to enable the assumed financial allowance for potential projects to be considered.

The inclusion of timing within the CE will allow an exploration of the rationality of intergenerational decision-making by respondents, and the related complex debates on inter-temporal decision-making and discounting. This is a key topic of interest and debate within macroeconomic theory. For example, many anomalies have been pointed out in inter-temporal choice, such as dynamic inconsistency, magnitude effects, sign effects, reference points, and savouring and dread (Loewenstein and Thaler, 1989). These anomalies suggest that individuals cannot have the same discounting rate for the variety of infrastructure development and management projects at any one time.

In terms of intergenerational decision-making, there are many economics discussions but these are categorised in three groups. The first is the overlapping generations model, the second is the altruistic linkage model and the third is non-overlapping generations model.

The most famous academic work belonging to the first model is probably Samuelson’s work in 1958. He discussed the consumption loan model of interest. He examined the interest rate on the inter-temporal exchange of several types of goods including both storable goods and non-storable goods, based on different demographic changes. He also considered the situation of population decline; in its case, the market rate of interest will be negative (Samuelson, 1958). In other words, people want to consume the goods as much and soon as possible if the goods won't increase in their amount more than the speed of decline in the population.

Barro also followed the first model group, and discussed the consumption loan model in the context of long-term public debt issues (Barro, 1974; Barro, 1979). Barro introduced the overlapping generations model for discussing the theme where "finite lives will not be relevant to the capitalisation of future tax liabilities so long as current generations are connected to future generations by a chain of operative intergenerational transfer" (Barro, 1974). The investment in infrastructure is often financed by long-term public debt; a key feature of infrastructure is its long life and the infrastructure users and those who have to reimburse the public debts are often different. Similar discussions are observed in the global warming debate. As Barro pointed out, if people care about the happiness or utilities of future and can consider them in their current decision-making, then this will pose no problems for infrastructure development and management even in the context of population decline. If not, we must develop good policies to cope with the potential problems. In this study, in order to discuss the validity of Barro's premises, such as intergenerational transfer and respondents' awareness of it, dummy variables were created to indicate whether respondents have properties to pass on in succession to future generations, whether they have descendants, and how long their life expectancy is.

Regarding the second model, Arrow and Dasgpta discussed the intergenerational equity using a simpler model premising a good and stable population considering future generations' utility to affect the current generation's welfare (Arrow, 1973; Dasgpta 1974a and 1974b). They defined the problem to be solved as maximising the level of welfare for the most unfortunate generation. The conclusion of this analysis is to insist on imposing the lowest welfare level on the current generation. In addition, an infinite flow of fair consumption creates the time series pattern of a tooth-shaped saw, but this does not embody the principle of intergenerational equity intuitively (Suzuki, 2006). Accordingly, these results cannot be accepted because of its situation without any benefits to the current generation and also the premise of a different context for population decline.

The premise of the third model is non-relations between the generations. It is a different context because it does not suggest any economic model based on the production and consumption of goods. It discusses only the evaluation of utility flow in each generation (Suzuki, 2006). If the level of per-capita utility flow is sustained on infrastructure service provision, this third model's hypothesis will be satisfied.

In this chapter, therefore, the first model and the third model are kept in the mind. If the current generation take the future generation's benefit into their decision making, Barro's theory in the first model will be accepted, but if not, then Samuelson's theory in the first model and the third model's discussion will be justified. Of course, as discussed in Samuelson's theory, it is very difficult to achieve the sustainability conditions of infrastructure service provision if people don't consider the interests of the future generation.

This chapter is organised into five sections. Following the introduction, Section 2 introduces the methodology for this study. The design of the study, characteristics of the respondents, questionnaire, analytical model and estimation formula of MWTP will be presented. Section 3 presents the results regarding the use of the infrastructure, the results of the conditional logit regression analysis and the estimation results of MWTP. Section 4 provides a discussion of the differences between depopulating areas and non-depopulating areas and the types of infrastructure. Finally, in the concluding section, the findings of the study are summarised and some suggestions for further research are provided.

9.2 METHODOLOGY

9.2.1 SUSTAINABILITY

As discussed in Chapter 5, the study in this chapter is based on the concept of sustainability. Four aspects – "society", "engineering", "environment" and "economy" – are used as a much better basis for considering the sustainability of infrastructure development (Sahely, Kennedy and Adams, 2005). Intertemporal quality continuity is also an arguable point of the discussion.

9.2.2 TYPES OF INFRASTRUCTURE

As in previous chapters, we chose public facilities as a point-type infrastructure; water and waste water management as a point-network-type infrastructure; and roads as a network-type infrastructure.

9.2.3 CHOICE EXPERIMENTS

As noted in the introduction, choice experiments (CE) are a stated preference method (Bateman et al., 2002) that uses questionnaires to create hypothetical markets through which respondents can state their preferences in monetary terms. Stated preference techniques are particularly useful when surrogate markets (such as the property and travel markets) do not exist through which individual preferences can be revealed. They are also the only method capable of measuring non-use values, i.e. wellbeing improvements that are unrelated to any use of the good. CE has its roots in Lancaster's Characteristic Theory of Value (Lancaster, 1966), and is based on the notion that goods and services can be described in terms of characteristics (or 'attributes') and the levels that these characteristics take. Respondents are presented with different combinations of these attributes and asked to choose their most preferred combination. CE enables information to be extracted from respondent choices between goods regarding: what attributes are significant determinants of the good, the implied ranking of these attributes, the value of changing more than one attribute at a time, and the total economic value of the good as long as price is included as an attribute (Bateman et al., 2002; Louviere et al., 2000; Hanley, Wright and Adamowicz, 1998). Choice modelling data can be analysed using a conditional logit regression within the context of a random utility model.

There is a very large literature discussing the pros and cons of stated preference techniques in general and CE in particular. Bateman et al. (2002) provide an extensive overview of known possible bias such as hypothetical bias (i.e. where respondents overestimate their hypothetical payment), insensitivity to the scope of the change, strategic bias (where respondents fail to reveal their true WTP in order to influence the survey results), etc. Many such biases are argued to be the result of bad survey design rather than inherent to the method itself. Some researchers have also criticised the stated preference method when applied specifically to the evaluation of infrastructure development (Fujii and Gärling, 2003), within the context of projections of transport demand. The stated preference method is based on the premise of the consistency of user preference, but various anomalies have been pointed out and are known as biases which can occur when undertaking stated preference studies (Yoshida, 2003; Kuriyama, 2008; Bateman et al., 2002) Referring to previous research results in cognitive psychology (Fujii et al., 2002a, 2002b) from a study on the evaluation of the nature of Yakushima Island using the contingent valuation method, which is another stated preference method (Kuriyama, Kitabatake and Ooshima et al., 2000), it was argued that preferences expressed in the survey were created expediently at the time of answering (constructive preference hypothesis) (Fujii and Gärling, 2003: p. 1); this can be interpreted as behavioural intention data in the theoretical frame of "attitude" used in social psychology (Fujii and Gärling, 2003: pp. 2–3).

A study by Kuriyama et al. (2000) was carefully designed and followed the National Oceanic and Atmospheric Administration (NOAA) best-practice guidelines for conducting the contingent valuation in order to avoid various biases. The results satisfied the scope test. Accordingly, this study has been accepted as reliable and relatively robust by environmental economists. Conversely, the following examination by the narrative protocol method (think-aloud method) by Fujii et al. showed that factors, regardless of the total budget and the justice of choices, could affect the responses, and that the less information was presented, the more conditions were assumed freely, which probably and significantly influenced responses (Fujii et al., 2002a).

Because of the questions surrounding possible inconsistency of preference and the indifference between attitude and intention, Fujii et al. (2002b) proposed the behavioural intention method, based on the factors affecting the consistency between intention and attitude instead of the utility function, and insisted on its advantage (Fujii and Gärling, 2003). Fujii et al (2002b)., however, insisted on recognising that taking strong customs as objectives and alternatives into the utility model used for the estimation in the contingent valuation model and choice modelling should not be called the stated preference model, but should be regarded as one variation of demand projections using attitude theory (Fujii and Gärling, 2003: p. 9). In fact, there are many previous studies that consider and analyse the most influential factors of stated preferences as parameters of the utility function in stated preference surveys. Fujii et al. (2002a) did not argue this point in their comparison study. In addition, a series of their previous discussions criticised the contingent valuation methods rather than the CE variant.

Indeed, the choice experiment is a stated preference method and it is based on the utility function, as is contingent valuation, but it also remedies some of the faults of contingent valuation. For example, the contingent valuation method evaluates the value of goods regardless of their marketability, whereas a choice experiment can evaluate a change in conditions. In addition, the stated preference made from multiple choices can avoid the tracking bias in contingent valuation. Furthermore, the evaluation of attributes can be conducted in choice experiments, but not in contingent valuation. Because of these advantages, choice modelling is superior to contingent valuation methods (Louviere, Hensher and Swait., 2000) when evaluating multidimensional goods, where trade-off between the various dimensions is of importance. It can therefore be considered appropriate to apply choice experiment in considering the sustainability of infrastructure development and management issues.

9.2.4 Sample design and Data collection

The population of interest involves Japanese residents in both depopulating and non-depopulating municipalities. The data was obtained from a closed-ended questionnaire accessed via the internet using True-Navi, which is the internet research service powered by the Nomura Research Institute. The samples were obtained from the monitors' database of True-Navi. The attributes of the samples were "over 20 years old" and "male and female". One sub-sample lived in depopulating municipalities, and answered the survey on the impact of population decline on infrastructure development and management in 2008, and the other sub-sample lived in other non-depopulating municipalities between 1975 and 2000 in 2009. Both sub-samples consisted of 1,000 respondents. The age and sex composition of these samples were checked after the answers were received from the respondents. The questionnaire survey was conducted over five days between 26 February 2009 and 2 March 2009 and ended as soon as the number of responses reached the target number.

9.2.5 *DESIGN OF THE QUESTIONNAIRE*

As described above, we use the choice experiment method to analyse public preferences for different infrastructure development and management options in Japan. To facilitate respondent choice tasks and reduce their cognitive burden the types of infrastructure were divided into two groups, Group A includes public facilities and water and waste water management, and Group B includes public facilities and roads. Respondents only answered questions from one of the groups. Note that respondents in both Groups A and B answered questions on public facilities, which will enable us to discuss the robustness of the answers on this topic by comparing responses for Group A with those for Group B.

The infrastructure development and management options are composed of five attributes, each varying at different levels. Table 56 describes each of these attributes and the levels that they take, for each type of infrastructure considered. Four attributes correspond to the four aspects of sustainability in which we are interested – society, engineering, environment and economy – while the fifth attribute represents the timing of development and management. The description of the sustainability attributes varies slightly between infrastructure types, reflecting the differences between these infrastructures. Depending on the infrastructure type, the society attribute is represented by the time it takes to reach public facilities/time to the main destination/or drinking water quality (At2); the engineering attribute is represented by safety of public facilities in terms of number of accidents or injuries per year (At3)[9]; the environment attribute is represented by landscape deterioration/ pollution (At4); and the economy attribute is represented by increases in user charges from using the facilities/increase in tax (At5)[10]. The fifth attribute is the timing of

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9 The accident rates in the water and waste water management sector were assumed from information from the municipalities. The road accident rate was calculated from the data on the length of the road (km) in 1999 and the annual number of road accidents multiplied by the average annual run distance (km) per car.

10 In most of the cases, users have to pay charges when they use the infrastructure, but in some cases a tax payment covers the cost of infrastructure development and maintenance. For such cases, the per capita construction investment in public facilities in 2005 was calculated as an approximation for measuring the economic aspects, and used as an alternative value to the economic aspect.

development and management expressed in years (At1). Our study design assumes that only the four aspects of infrastructure sustainability considered and the timing of development can significantly determine the utility of the respondents.

The profiles that are surrounded by bold lines in Table 56 show the status quo. The intention of our survey is to investigate respondent preferences when the current development and management situation for infrastructure takes place in 2040. If the respondents care only about the timing of development and management and not the other attributes, then profiles presented in earlier times should be preferred.

Using experimental design, the levels of the attributes were combined into various choice options or profiles. The full enumeration of possible choice profiles, considering only the aspects of "society", "engineering" and "environment", generated 48 choice profiles for public facilities, 36 for water and waste water management and 48 for roads. Using experimental design methods, these were reduced to 16 profiles each. The 16 profiles generated for the three aspects of infrastructure sustainability were then combined with the remaining two aspects, "timing of development" and "economy", generating a total of 1200 profiles for public facilities, 900 profiles for water and waste water management, and 1200 profiles for roads.

The profiles generated by this process were then packaged into triplets to be presented as choice cards to respondents. Each choice card triplet contained the status quo option (on the left-hand side) and two alternative profiles, selected randomly from the set of experimentally designed profiles described above. This procedure was repeated six times for each respondent so that each respondent was presented with 6 choice cards, and was asked to choose their most preferred option for each of the 6 triplets.

Table 56 Attributes and levels for each infrastructure type

Public facilities

Attributes	← Level →		Status Quo		
At1Year: Timing of development and management	2100	2055	2040	2025	2010
At2TD: Time distance to the public facilities (social aspect)	time distance will become twice as much, _____(2*QA1)	Time distance will become 1.5 times as much, _____(1.5*QA1)	Time distance will become the same _____(QA1)	Time distance will become 0.5 times as much, _____(0.5*QA1)	
At3NofInjure: Safety on public facilities (engineering aspect)	Annually 5 persons will be injured	Annually 1 person will be injured	Annually 0.2 persons will be injured	Annually 0.04 persons will be injured	
At4Landscape: Landscape deterioration on public facilities (environmental aspect)		Deteriorating the outward appearance owing to insufficiently cleaning the outside wall and not caring for plants in the future	Keep the present situation even in the future	Improving the outward appearance due to cleaning the outside wall and gardening even in the future	
At5Econ000yen: Increase in user charge (economic aspect)	Potential cost of using facilities will decline from present monthly 1000 yen (QA1) to half as much, monthly 500 (0.5*QA1) yen, and result in a decline in user fees or local taxes	Potential cost of using facilities will be the same as much, monthly ***1000 yen (QA1),*** as that of the present	Potential cost of using facilities will increase from present monthly ***1000 yen (QA1)***, to **twice as much**, monthly ***2000(2*QA1) yen,*** and result in an increase in user fees or local taxes	Potential cost of using facilities will increase from present monthly ***1000 yen (QA1)*** to **four times as much**, monthly ***4000(4*QA1) yen,*** and result in an increase in user fees or local taxes	Potential cost of using facilities will increase from present monthly ***1000 yen (QA1)*** to **eight times as much**, monthly ***8000(8*QA1) yen,*** and result in the increase in user fee or local taxes

Water and waste water management

Attributes	← Level →		Status Quo		
At1Year: Timing of development and management	2100	2055	2040	2025	2010
At2Regulation: Water quality (social aspect)		Not satisfied with the regulation for drinking, but no problem with the usage of cooking, washing and so on.	Satisfied with the regulation for drinking, but sombody minds its smell and taste.	Satisfied with the regulation for drinking and no complaints about the taste and smell of water	
At3NofAccidents: Frequency of leaking water (engineering aspect)	Daily 20 accidents of leaking water, which is 5 times as much as the present situation, from the water supply or waste water drainage pipes in one prefecture	Daily 10 accidents of leaking water, which is 2.5 times as much as the present situation, from the water supply or waste water drainage pipes in one prefecture	Daily 4 accidents of leaking water, which is the same as the present situation, from the water supply or waste water drainage pipes in one prefecture	The situation will be improved and there will be no leaking accidents except for scheduled maintenance.	
At4EnvQuality : Pollutions (environmental aspect)		Odour, soil contamination, water quality deterioration of discharged water will not be ignoable and significant damage will occur	Odour, soil contamination, water quality deterioration of discharged water will be ignorable.	The waste water management will be perfect and the problem of odour, soil contamination, water quality deterioration of discharged water will not occur at all.	
At5Econ000yen: Increase in user charge (economic aspect)	User charge will decline to monthly 500 yen (0.5*QA17) compared with the present charge monthly 1000 yen (QA 17).	User charge will keep the same level as the present charge monthly 1000 yen (QA 17).	User charge will increase up to monthly 1500 yen (1.5*QA17) compared with the present charge monthly 1000 yen (QA 17).	User charge will increase up to monthly 2000 yen (2.0*QA17) compared with the present charge monthly 1000 yen (QA 17).	User charge will increase up to monthly 2500 yen (2.5*QA17) compared with the present charge monthly 1000 yen (QA 17).

Road

Attributes	← Level →		Status Quo		
At1Year: Timing of development and management	2100	2055	2040	2025	2010
At2TD: Time distance to the main destination (social aspect)	Time distance will become twice _____(2*QB5) as much	Time distance will become 1.5 times _____(1.5*QB5) as much	Time distance will become the same _____(QB5)	Time distance will become 0.5 times _____(0.5*QB5) as much	
At3NofAccidents: Road accident (engineering aspect)	Possibility of one accident occurring annually per car owing to insufficient maintenance of roads, which is three times as much as thepresent situation	Possibility of annually occuring 0.7 accidents per a car owing to insufficient maintenance of roads, which is twice as much as the present situation	Possibility of annually occuring 0.3 accidents per a car owing to insufficient maintenance of roads, which is the same asthe present situation	No accidents will occur per car owing to insufficient maintenance of roads, which is improved from the present situation	
At4EnvRecov: Landscape deterioration on road (environmental aspect)		Removing closed road structures and pavements and recovering nature	As present, just closing the abolished road with fences but not recovering nature	Just closing the abolished road with sign and not recovering nature. (At present, closed road often have fences)	
At5Econ: Increase in tax rate (economic aspect)	Fuel tax rate will be half (26.9yen/l) of the present level (53.8yen/l) and the fuel price will be about 75 yen/l.	Fuel tax rate will be the same (53.8yen/l) as the present level (53.8yen/l) and the fuel price will be about 110 yen/l.	Fuel tax rate will be 1.5 times (80.7yen/l) as much as the present level (53.8yen/l) and the fuel price will be about 135 yen/l.	Fuel tax rate will be twice (107.6yen/l) as much as the present level (53.8yen/l) and the fuel price will be about 155 yen/l.	Fuel tax rate will be twice (134.5yen/l) as much as the present level (53.8yen/l) and the fuel price will be about 185 yen/l.

Note 1: Columns enclosed by bold lines show the status quo.
Note 2: Q in the table column reflects the answers from respondents to the survey and differs among respondents.

Accordingly, 1,000 respondents multiplied by three profiles in one choice set multiplied six times was finally equal to 18,000 lines of data obtained from the survey for each group for the following analysis. This means that public facilities and water and waste water management in Group A and public facilities and roads in Group B produced 18,000 samples each before invalid samples were filtered out. This means that 36,000 samples were produced for the public facilities and 18,000 samples for each of the other two types of infrastructure. An example of a choice card triplet containing 3 profiles, for public facilities, is shown in Figure 97.

	Choice 1	Choice 2	Choice 3
At1Year: Timing of development and management	2040	2100	2025
At2TD: Time distance to the public facilities (social aspect)	Time distance will become the same _____(QA1)	Time distance will become the same _____(QA1)	Time distance will become the same _____(QA1)
At3NofInjure: Safety on public facilities (engineering aspect)	Annually 0.2 persons will be injured	Annually 0.2 persons will be injured	Annually 0.04 persons will be injured
At4Landscape: Landscape deterioration on public facilities (environmental aspect)	Keep the present situation even in the future	Improving the outward appearance due to cleaning the outside wall and gardening even in the future	Keep the present situation even in the future
At5Econ000yen: Increase in user charge (economic aspect)	Potential cost of using facilities will increase from present monthly 1000 yen (QA1) to twice as much , monthly 2000(2*QA1) yen, and result in an increase in user fees or local taxes	Potential cost of using facilities will be the same, monthly 1000 yen (QA1) as much as that of the present	Potential cost of using facilities will increase from present monthly 1000 yen (QA1) to four times as much, monthly 4000(4*QA1) yen, and result in an increase in user fees or local taxes
	□	□	□

Figure 97 Example of choice modelling for public facilities.

In the modelling approach for estimation in the choice experiment, a conditional logit model is used for testing the subject specific fixed effects. In choice modelling, the respondents give their preferences from three profiles in one choice set. This means that the effect of the choice set should be considered in the regression analysis.

The formula for the conditional logit regression model adds the dummy variables to the generalised estimating equation, in a choice experiment, on each choice set as follows (Kleinbaum and Klein, 2010);

$$\text{logit } P(x) = \beta_0 + \beta_1 x + \sum_{i=1}^{n} \gamma_i V_i \qquad (9.1)$$

where

$$V_i = \begin{cases} 1 \text{ for subject i} \\ 0 \text{ otherwise} \end{cases}$$

γ: parameters for the dummy variables

We develop two basic models for analysing preferences for the attributes of interest, namely the four sustainability aspects plus the timing of development and management of infrastructure, described in Section 2.4. The difference between these models is in the treatment of the timing of development and management. The first model considers the multiple timings as one continuous variable named "At1Year"; while the second basic model models the different timings separately as dummy variables termed "At1Y2025", "At1Y2040", "At1Y2055" and "At1Y2100".

Model 1 contains the following variables: the variable of timing of infrastructure development and management, termed "At1Year"; the time distance from the respondents' homes to public facilities, termed "At2TD", which is a continuous variable representing the social aspect; the number of injuries on the engineering aspect, termed "At3NofInjure", which is a continuous variable; the level of landscape restoration and conservation as the environmental aspect, termed "At4Landscape", which is a discrete variable; the economic burden of infrastructure development and management as the economic aspect, termed "At5Econ000yen", which is a continuous variable; and, strata variables termed "strata(STRNo)", which are categorical data. These variables are for public facilities. The variables for the other types of infrastructure use different descriptions, and the framework with the four aspects of the sustainability of infrastructure development and management is applied as shown in Table 57.

The utility functions are represented using the indirect conditional utility (V_1, V_2, V_3, V_4). The following formula is for public facilities; for the other two infrastructure types the structure of the formulae used is the same but the names of the variables are changed (Model 1):

$$V_1 = At1Year + At2TD + At3NofInjure + At4Landscape + At5Econ000yen + strata\ (STRNo) \tag{9.2}$$

In Model 2, the variables are the same, except for the variables for the timing of infrastructure development and management, as timing is split into four dummy variables: “At1Y2025”, ”At1Y2040”, “At1Y2055” and “At1Y2100” (Model 2):

V_2= At1Year2025 + At1Year2040 + At1Year2055 + At1Year2100 + At2TD+At3NofInjure+At4Landscape+At5Econ000yen+strata (STRNo) (9.3)

We also develop two further derivative models, containing interactions between the attributes in Models 1 and 2 and other dummy variables, to test the effect of status quo bias, population decline and intergenerational considerations of respondents. These interaction models are as follows:

V_3=At1Year+At2TD+At3NofInjure+At4Landscape+At5Econ000yen+Dummy*(At1Year+At2TD+At3NofInjure+At4Landscape+At5Econ000yen)+strata(STRNo) (Model 1 with interactions)

(9.4)

V_4=At1Y2025+At1Y2040+At1Y2055+At1Y2100+At2TD+At3NofInjure+At4Landscape+At5Econ000yen+Dummy*(At1Y2025+At1Y2040+At1Y2055+At2TD+At3NofInjure+At4Landscape+At5Econ000yen)+strata(STRNo) (Model 2 with interactions)

(9.5)

The generic ‘dummy’ variable in both interaction models 9.4 and 9.5 represents “CardNo”, “AorB”, “pd”, “descendant”, “property”, “lifexpct” and “live”. These are described in Table 57 below.

To test for the presence of status quo bias, a tendency to choose the status quo over any other options, the variable of “CardNo” was introduced. “CardNo” takes the value of 1 when the profile in a card is positioned on the left hand side, that is, corresponds to the status quo, and 0 if not. Recall that in the three choice sets that were presented in the survey to each respondent, for each infrastructure type, the base case assuming that the current infrastructure development situation will be happening in 2040 is always presented in the most left-hand side position every time as a benchmark. We therefore test for possible status quo bias using the dummy variable "CardNo".

Furthermore, because the questionnaire was too long to be conducted on all three types of infrastructure, the samples were divided into two groups, namely, A and B. With regard to water and waste water management and roads, the samples were only from either A or B. For public facilities, however, both the A and B samples were used for analysis. We should therefore consider the differences between both sample groups. In order to check the difference, the variable of "AorB" was introduced, in particular, for public facilities. "AorB" takes the value of 1 when the sample is from A, but if not if the value is 0. The formulae are as follows:

The main interest of this study is in the relationship between population decline and infrastructure sustainability. The respondents were sampled from both depopulating areas and non-depopulating areas. The variable of "pd" represents this sample difference; "pd" takes the value of 1 when the sample is from a depopulating area, otherwise the value is 0.

Finally, in order to check the validity of the theory on intergenerational equity, we introduced four variables. The first two variables are related to Richard and Barro's theory, the overlapping generation model. The variable "descendant" is 1 when respondents have either children or grandchildren, and the variable "property" is 1 when respondents have any properties which will be passed on to the next generation. If Richard and Barro's theory is correct, these two variables should be positively and statistically significant. On the other hand, the rationality of decision-making of respondents should be tested more directly. For this purpose, the variables "lifexpct" and "live" were introduced. The variable "lifexpct" is the number of years of life expectancy assumed by each respondent. On the other hand, "live" is the corresponding dummy variable – when the questioned timing of infrastructure development is less than life expectancy, the value of the variable will be 1. This variable can test the sharpness of the rationality of respondents. If this "live" variable sensitively responds to the timing of infrastructure development, the rationality of the responses can be considered reliable. On the other hand, if the response is not sensitive it could be considered that the rationality of respondent preferences is not sharp but rather vague, which means that responses from ordinary citizens do not provide sufficient basis when it comes to the discussion of options involving small differences in the timing and level of infrastructure development and management. In this case, we could argue that only general policy options should be asked of citizens, while the detailed design and policy of infrastructure development and management should be determined by infrastructure managers.

All the variables used in the analysis are shown in Table 57. In all cases, the four models described were estimated using the conditional logit model.

The data for the analysis consisted of both numeric and qualitative data, and the initial hypotheses of coefficient signs are shown in Table 58 for each infrastructure type and for the four sustainability aspects plus the timing of development.

Table 57 Summary of variables used in the analysis

Category of variable		Types of infrastructure: Public facilities	Water and waste water management	Road	Explanation of variable
Models 1 and 2 with interactions	Models 1 and 2	At1Year	At1Year	At1Year	Variable of timing of infrastructure development and management
		At2TD	At2Regulation	At2TD	Variable for the social aspect
		At3NofInjure	At3NofAccidents	At3NofAccidents	Variable for the engineering aspect
		At4Landscape	At4EnvQuality	At4EnvRecov	Variable for the environmental aspect
		At5Econ000yen	At5Econ000yen	At5Econ	Variable for the economical aspect
	Dummy variables	At1Y2025			Dummy variable to test the preference on the specific development year. The value is 1 when the profile is assumed to be realised in 2025, but if not the value = 0
		At1Y2040			Dummy variable to test the preference on the specific development year. The value is 1 when the profile is assumed to be realised in 2040, but if not the value = 0
		At1Y2055			Dummy variable to test the preference on the specific development year. The value is 1 when the profile is assumed to be realised in 2055, but if not the value = 0
		At1Y2100			Dummy variable to test the preference on the specific development year. The value is 1 when the profile is assumed to be realised in 2100, but if not the value = 0
		AorB	-	-	Dummy variable to test the difference between Group A and Group B. The value is 1 when the sample is from A, but if not the value = 0
		CardNo			Dummy variable to test the bias of status quo. The value is 1 when the card is positioned in the most left hand side (i.e. is the status quo), but if not the value = 0.
		pd			Dummy variable to confirm the differences between depopulating areas and non-depopulating areas. The value is 1 when the sample is from the depopulating area, but if not the value = 0.
		descendant			Dummy variable of descendant. The variable is 1 when respondents have either children or grandchildren.
		property			Dummy variable for the ownership of properties inherited. The variable is 1 when respondents have any properties which will be passed to the next generation.
		lifexpct			Variable for life expectancy of respondent. The value of the variable is the number of years of life expectancy answered by each respondent.
		live			Dummy variable for life expectancy. If the questioned timing of infrastructure development is less than life expectancy, the value of the variable will be 1.

Table 58 Types of data and initial hypotheses of signs for each of choice experiment

	Public facilities		Water and waste water management		Road	
	Data type	Hypothesis of sign	Data type	Hypothesis of sign	Data type	Hypothesis of sign
Timing of development	Numeric	−	Numeric	−	Numeric	−
Social aspect	Numeric	−	Qualitative	−	Numeric	−
Engineering aspect	Numeric	−	Numeric	−	Numeric	−
Environmental aspect	Qualitative	+	Qualitative	+	Qualitative	+
Economic aspect	Numeric	−	Numeric	−	Numeric	−

The MWTP is estimated using the following formula (9.6):

$$\mathrm{MWTP}_{k,a} = \frac{\alpha_{k,a}}{\alpha_{k,Econ}} \qquad (9.6)$$

where

$MWTP_{k,a}$: Marginal willingness to pay in each infrastructure type and attribute

a : Suffix which shows the attributes of infrastructure sustainability and timing of development,
1 = timing of development, 2 = social aspect, 3 = engineering aspect, 4 = environmental aspect

9.3 RESULTS

9.3.1 RESPONSE STATISTICS

This section reveals the descriptive statistics for the original sample sets. This section also shows the results of filtering the original samples; for example, some respondents provided irrational life expectancies such as 100 year-long from a 40 year old respondent. As the answers from this type of respondent are not rational answers, they were therefore excluded.

The basic descriptive statistics of the explanatory variables for the conditional logit regression analysis are shown in Table 59 for depopulating/non-depopulating municipalities and Group A and Group B.

This table shows that the averages, medians and standard deviations of the explanatory variables are almost the same but that some data differs. The average time distance and standard deviation to the public facilities (At2TD) differs between respondents in depopulating municipalities and non-depopulating municipalities. In particular, the size of the standard deviation between depopulating and non-depopulating municipalities is reversed in Group A and Group B. The user charge for public facilities (At5Econ000yen) is completely different for the average and standard deviation between depopulating/non-depopulating areas and Group A/Group B. The user charge (At5Econ000yen) for water and waste water management and time distance for an ordinary destination by road (At2TD) appears to be slightly different between depopulating and non-depopulating areas.

Table 59 Basic descriptive statistics of the original samples

Public Facilities

			Choice	At1Year	At2TD	At3NofInjure	At4Landscape	At5Econ000yen
Mean	Total		0.33	35.21	14.23	1.15	2.00	5.48
	Depopulated municipalities		0.33	35.18	13.55	1.16	2.00	5.26
	Non-depopulated municipalities		0.33	35.24	14.91	1.15	2.00	5.70
	Group A	Total	0.33	35.30	14.25	1.15	2.00	5.82
		Depopulated municipalities	0.33	35.07	13.65	1.16	2.01	5.42
		Non-depopulated municipalities	0.33	35.54	14.85	1.15	2.00	6.23
	Group B	Total	0.33	35.11	14.20	1.15	2.00	5.13
		Depopulated municipalities	0.33	35.28	13.46	1.16	2.00	5.11
		Non-depopulated municipalities	0.33	34.95	14.97	1.15	2.00	5.16
Median	Total		0.00	31.00	10.00	0.50	2.00	3.00
	Depopulated municipalities		0.00	31.00	10.00	0.50	2.00	3.00
	Non-depopulated municipalities		0.00	31.00	10.00	0.50	2.00	3.00
	Group A	Total	0.00	31.00	10.00	0.50	2.00	3.00
		Depopulated municipalities	0.00	31.00	10.00	0.50	2.00	3.00
		Non-depopulated municipalities	0.00	31.00	10.00	0.50	2.00	3.00
	Group B	Total	0.00	31.00	10.00	0.50	2.00	3.00
		Depopulated municipalities	0.00	31.00	10.00	0.50	2.00	3.00
		Non-depopulated municipalities	0.00	31.00	10.00	0.50	2.00	3.00
Standard deviation	Total		0.47	25.54	11.95	1.82	0.60	19.34
	Depopulated municipalities		0.47	25.62	11.91	1.83	0.60	17.55
	Non-depopulated municipalities		0.47	25.45	11.95	1.82	0.60	21.00
	Group A	Total	0.47	25.60	12.52	1.82	0.60	**25.00**
		Depopulated municipalities	0.47	25.59	**13.23**	1.82	0.60	22.43
		Non-depopulated municipalities	0.47	25.60	**11.73**	1.82	0.60	27.32
	Group B	Total	0.47	25.47	11.35	1.82	0.60	**11.08**
		Depopulated municipalities	0.47	25.65	**10.45**	1.83	0.60	10.69
		Non-depopulated municipalities	0.47	25.29	**12.16**	1.82	0.60	11.48
Response	Total		11,990					
	Depopulated municipalities		6,020					
	Non-depopulated municipalities		5,970					
	Group A	Total	5,998					
		Depopulated municipalities	2,998					
		Non-depopulated municipalities	3,000					
	Group B	Total	5,998					
		Depopulated municipalities	3,022					
		Non-depopulated municipalities	2,970					

Water and waste water management

		Choice	At1Year	At2Regulatio	At3NofAccidents	At4_EnvQuality	At5_Econ(000yen)
Mean	Total	0.33	35.30	2.00	6.82	2.00	8.21
	Depopulated municipalities	0.33	35.07	2.00	6.80	1.99	8.33
	Non-depopulated municipalities	0.33	35.54	2.00	6.84	2.00	8.10
Median	Total	0.00	31.00	2.00	4.00	2.00	6.00
	Depopulated municipalities	0.00	31.00	2.00	4.00	2.00	6.00
	Non-depopulated municipalities	0.00	31.00	2.00	4.00	2.00	6.00
Standard deviation	Total	0.47	25.60	0.60	6.55	0.60	10.48
	Depopulated municipalities	0.47	25.59	0.59	6.53	0.60	13.17
	Non-depopulated municipalities	0.47	25.60	0.60	6.57	0.60	6.80
Response	Total	5,998					
	Depopulated municipalities	2,998					
	Non-depopulated municipalities	3,000					

Road

		Choice	At1Year	At2TD	At3NofAccidents	At4EnvRecov	At5_Econ(000yen)
Mean	Total	0.33	35.11	31.36	0.25	2.00	137.61
	Depopulated municipalities	0.33	35.28	29.24	0.25	2.00	137.71
	Non-depopulated municipalities	0.33	34.95	33.57	0.24	2.00	137.51
Median	Total	0.00	31.00	20.00	0.07	2.00	135.00
	Depopulated municipalities	0.00	31.00	16.00	0.07	2.00	135.00
	Non-depopulated municipalities	0.00	31.00	20.00	0.07	2.00	135.00
Standard deviation	Total	0.47	25.47	46.60	0.36	0.60	39.67
	Depopulated municipalities	0.47	25.65	45.10	0.36	0.60	39.53
	Non-depopulated municipalities	0.47	25.29	48.03	0.36	0.60	39.81
Response	Total	5,992					
	Depopulated municipalities	3,022					
	Non-depopulated municipalities	2,970					

9.3.2 *SAMPLE CHARACTERISTICS*

The sex and age composition of respondents are shown in Table 60, compared with the results from the National Census of Japan in 2005. It can be said that the components of the two are almost the same. With regard to the composition of depopulating and non-depopulating areas and Group A/Group B, we tried to ensure the same sample size distribution, that is, 500 samples in each column, and the final sample allocation is shown in Table 61.

Table 60 Sex and age composition of the respondents and the national census results in 2005

Samples (2008)		Ages					
		20s	30s	40s	50s	60s	Total
Total	Male	178	208	188	230	188	992
		17.9%	21.0%	19.0%	23.2%	19.0%	100.0%
	Female	172	206	186	236	208	1008
		17.1%	20.4%	18.5%	23.4%	20.6%	100.0%
	Total	350	414	374	466	396	2000
		17.5%	20.7%	18.7%	23.3%	19.8%	100.0%
Group A	Male	89	104	94	115	94	496
		17.9%	21.0%	19.0%	23.2%	19.0%	100.0%
	Female	86	103	93	118	104	504
		17.1%	20.4%	18.5%	23.4%	20.6%	100.0%
	Total	175	207	187	233	198	1000
		17.5%	20.7%	18.7%	23.3%	19.8%	100.0%
Group B	Male	89	104	94	115	94	496
		17.9%	21.0%	19.0%	23.2%	19.0%	100.0%
	Female	86	103	93	118	104	504
		17.1%	20.4%	18.5%	23.4%	20.6%	100.0%
	Total	175	207	187	233	198	1000
		17.5%	20.7%	18.7%	23.3%	19.8%	100.0%
National Census (2005)		Ages					
		20s	30s	40s	50s	60s	
	Male	18.8%	22.0%	18.7%	22.3%	18.2%	
	Female	18.0%	21.5%	18.5%	22.5%	19.4%	
	Total	18.4%	21.8%	18.6%	22.4%	18.8%	

Table 61 The composition of the respondents for depopulating/non-depopulating areas and Group A/Group B

		Non-depopulated municipalities	Depopulated municipalities
Group A	Count	500	500
	%	50.0%	50.0%
Group B	Count	495	505
	%	49.5%	50.5%
Total	Count	995	1005
	%	49.8%	50.3%

Next, the statistical differences on coefficients of regression analysis to test the differences of sample nature on both the Group and the area are described.

In terms of Group A and Group B differences, the At2 Time distance is different with 10% statistical significance and the At5 Economy factor is different with 1% statistical significance. This suggests that there may be some differences according to the geographical distribution in the municipalities in which Group A respondents and Group B respondents live.

Table 62 Statistical test of the differences on coefficients between Group A and Group B

Group A or B	Coefficient A	Standard Error of Coefficient A	Coefficient B	Standard Error of Coefficient B	t-value		1%sig.	5%sig.	10%sig.
At1Year	-0.004	0.001	-0.004	0.001	0.159				
At2 Time distance	-0.029	0.003	-0.036	0.003	1.822	*			
At3 Not Injure	-0.341	0.012	-0.345	0.012	0.201		2.576	1.960	1.645
At4 Landscape	0.279	0.029	0.242	0.030	0.876				
At5 Econ00yen	-0.065	0.007	-0.115	0.008	4.707	***			
Sample size		18000		18000					

At2 Time distance, At3 Safety (Not Injure) and At5 Economy aspects can be observed as significantly different at more than 5% statistical difference in terms of the responses on population decline. The respondents in non-depopulating areas are more sensitive on At2 Time Distance and At5 Economy aspects than those in depopulating areas.

Table 63 Statistical test of the differences in coefficients between depopulating areas and non-depopulating areas

Population decline or Non population decline	Coefficient of Population decline	Standard Error of Coefficient of Population decline	Coefficient of NON Population decline	Standard Error of Coefficient of NON Population decline	t-value		1%sig.	5%sig.	10%sig.
At1Year	-0.004	0.001	-0.005	0.001	1.086				
At2 Time distance	-0.023	0.002	-0.031	0.003	2.312	**			
At3 Not Injure	-0.396	0.013	-0.311	0.012	4.789	***	2.576	1.960	1.645
At4 Landscape	0.239	0.030	0.282	0.030	1.011				
At5 Econ00yen	-0.052	0.005	-0.096	0.008	4.743	***			
Sample size		18000		18000					

Interestingly, there is no difference observed in the At1 Year (Timing) and At4 Landscape (Environment). It may be that all respondents share common sense on these two aspects of infrastructure development.

9.3.3 INTERGENERATIONAL DECISION-MAKING ISSUES

For the discussion of intergenerational decision-making issues, Table 64 shows the number of answers and the ratio for “children”, “grandchildren”, “descendants”, and “property”. Both Group A and Group B show almost the same composition for these items and 88% of respondents had descendants, although only 25% of respondents had property to pass down to a future generation.

Table 64 Children, grandchildren, descendants and property situation of respondents

		children	grandchildren	descendants	property
Group A	No	880	128	880	263
	%	88.0%	12.8%	88.0%	26.3%
Group B	No	871	136	872	250
	%	87.1%	13.6%	87.2%	25.0%

9.3.4 USE OF INFRASTRUCTURE

Table 65 and Table 66 show the average time distance to public facilities and the annual user charge paid by the respondents. Most respondents could arrive at public facilities within 30 minutes, and 20% of respondents did not pay any user charge when they used public facilities. This is because some public facilities do not ask users to pay the cost in Japan, and the local government covers the cost of the development as well as the maintenance and operation of the public facilities from tax revenues.

Table 65 Time distance to public facilities

Time distance to public facilities (minutes)	No. responses	%
0	2	0.1%
Between 0 and 5	418	20.9%
Between 5 and 10	532	26.6%
Between 10 and 30	586	29.3%
Between 30 and 60	26	1.3%
Over 60	2	0.1%
No use of public facilities	434	21.7%
Total	2000	
Mean	13	
Median	10	
Maximum	120	
Minimum	0	

Table 66 Annual charge for public facilities

Annual charge payment for public facilities (JPY)	No. responses	%
0	1,387	69.4%
Between 0 and 10	1	0.1%
Between 10 and 100	3	0.2%
Between 100 and 1,000	77	3.9%
Between 1,000 and 10,000	50	2.5%
Between 10,000 and 100,000	45	2.3%
Over 100,000	3	0.2%
No use of public facilities	434	21.7%
Total	2,000	
Mean	13,906	
Median	2,000	
Maximum	350,000	
Minimum	10	

Note: descriptive statistics only cover the sample more than 0.

9.3.5 Respondent rationality

When discussing intergenerational decision-making, the survival situation of respondents is very important. Figure 98 illustrates the distribution of the survival ratio of respondents in 2010, 2025, 2040, 2055 and 2100. Survival ratio is defined by the following formula:

$$\text{Suvival ratio} = \frac{\text{The number of suvivors in each timing}}{\text{Total number of respondents}} \quad (9.7)$$

Once the age of the respondent and their anticipated life expectancy are added together, the number is compared with the timing of development and management for 2010, 2025, 2040, 2055 and 2100. If the added number is less than the timing, the respondent will still be alive; then, the number of the survivors will be counted and divided by the total number of respondents. This quotient of the division is the survival ratio.

As can be seen, the survival ratio rapidly declines between 2025 and 2040. This is because the baby-boomer generation is expected to die in this period. In addition, 2040 is a key year as it is the inflection point of the survival rate curve, and is therefore a kind of benchmark year for the choice modelling survey.

The distribution of life expectancy years plus age of respondents is shown in Figure 99. The average life expectancy in Japan is less than 90 years, and accordingly, the peak number is expected to be positioned at less than 90 years. This expectation seems to be satisfied according to the following figure. At the same time, an added life expectancy, plus age of over 100 years also occurs in each year up to the respondents' age; however, these answers can be considered as inadequate and rather optimistic and they should be removed from the estimation steps that follow.

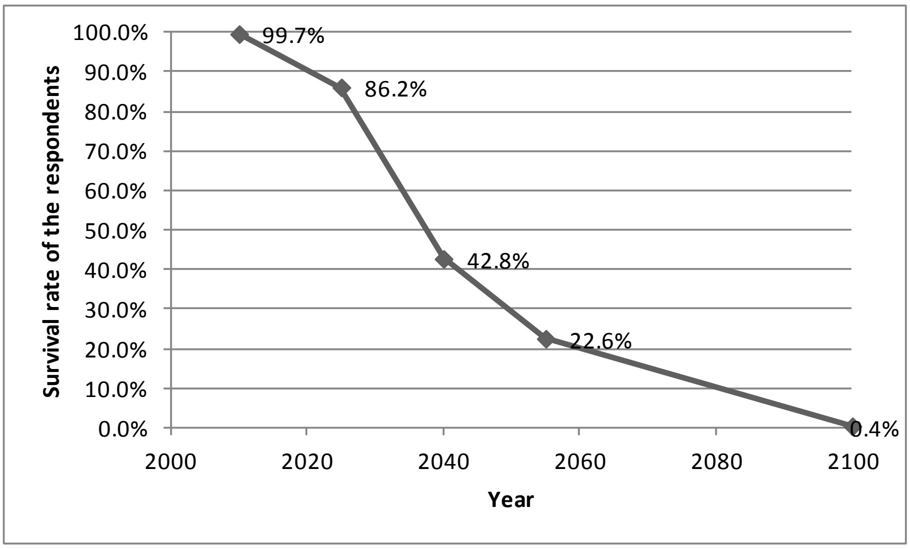


Figure 98 Distribution of survival ratio of respondents in each year.

Only samples in which the age plus life expectancy was between 60 years and 100 years were, therefore, selected for the following analysis.

		Group A		Group B	
Age + life expectancy years	25	0.10%		0.00%	
	30	0.20%		0.10%	
	35	0.20%		0.10%	
	40	0.80%		0.40%	
	45	0.50%		0.40%	
	50	0.60%		0.60%	
	55	0.60%	3.00%	0.50%	2.10%
	60	1.70%		2.70%	
	65	3.50%		3.70%	
	70	10.60%		8.60%	
	75	15.70%		17.90%	
	80	26.00%		25.20%	
	85	23.70%		23.30%	
	90	10.60%		10.00%	
	95	1.90%		2.50%	
	100	1.60%	95.30%	2.60%	96.50%
	over	1.70%	1.70%	1.40%	1.40%

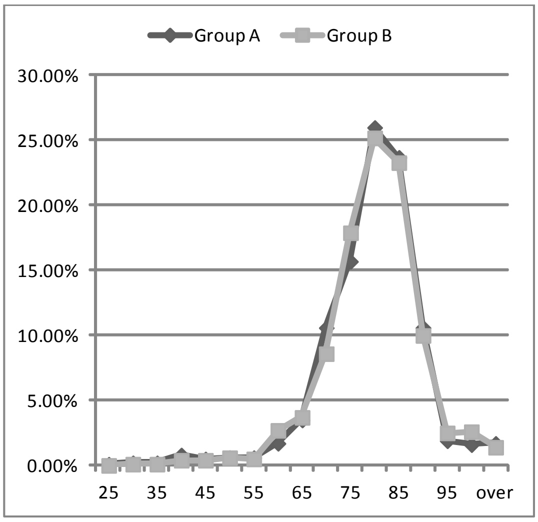


Figure 99 Age plus life expectancy years of respondents

9.3.6 Conditional logit analysis

This section describes the balance between the four aspects of infrastructure sustainability – “society”, “the environment”, “economy” and “engineering” – plus the timing of infrastructure development. In addition, all the sign hypotheses are satisfied. Accordingly, all the results should be accepted for the following discussion of the base models. The tables include not only Models 1 and 2, but also the derivative models with interactions for discussing bias checks, population decline and intergenerational decision-making.

9.3.6.1 Public facilities

The results of the conditional logit regression analysis for public facilities are shown in Table 67 and Table 68.

9.3.6.1.1 Model 1

In Model 1-1, sign conditions are satisfied and all variables are statistically significant. “At1Year” and “At2TD” are the maximum two orders of numbers but the others are one order. In light of this, the magnitude of the coefficient “At1Year” is smaller than others.

In terms of status quo bias, the variable “CardNo” is statistically significant. Some position bias on the cards, in particular “At3NofInjure” (engineering aspect), “At4Landscape” (environmental aspect) and “At5Econ000yen” (economic aspect) can therefore be seen. On the other hand, interestingly, the results of the estimation for the variable “At1Year” (timing of infrastructure development and management) and “At2TD” (social aspect) are not influenced by the card position, i.e. by the status quo.

Sample bias was also checked by the dummy variables of “AorB”, and the result suggests that there is no bias in the sample difference. Time distance to public facilities seems to be slightly different between sample Group A and sample Group B, but this can be ignored.

Population decline was main concern of this study, but regrettably, the interaction effect of population decline is not statistically significant, with the exception of the “At3NofInjure” variable.

This means that whether respondents live in depopulating areas or not does not make any difference to the development of policy on public facility development and management, even when society faces a projected population decline.

The interaction effects of the four variables test the hypothesis of the rationality of intergenerational decision-making. The variables for “descendants” and “property” are typical explanatory devices in the Richard and Barro theorem. Unfortunately, neither of these variables can explain any significant differences in the four aspects and timing of infrastructure sustainability. It suggests the respondents gave their preference based on public facility development and management irrespective of the situation for descendants and properties passed down to successive generations.

Furthermore, respondent life expectancy is not significantly related to the preference statement on the development and management choice sets, apart from the economic issue while “live”, which is very similar variable of “lifexpct”, shows a different result. Thus “live” shows significant negative interaction coefficients with “At1Year” and “At3Injure”. In terms of “At1Year”, the coefficient sign shows positive and this means that later development and management with payments is preferable within their expected life time, and if the timing is beyond their expected life period, earlier development and management with payment are preferred. This suggests that respondents decide and take responsibility within their expected life period.

Table 67 Conditional logit regression analysis results for Model 1 on public facilities

Variables	Basic Model 1 Group															
	Basic Model 1-1		Basic Model 1-CardNo		Basic Model 1-AorB		Basic Model 1-pd		Basic Model 1-dscndnts		Basic Model 1-property		Basic Model 1-lifexpct		Basic Model 1-live	
	coef	p	coef	p	coef	p	coef	p	coef	p	coef	p	coef	p	coef	p
At1Year	-0.004	0.000 ***	-0.004	0.210	-0.005	0.000 ***	-0.005	0.000 ***	-0.005	0.000 ***	-0.005	0.000 ***	-0.004	0.002 ***	-0.017	0.000 ***
At2TD	-0.018	0.000 ***	-0.003	0.400	-0.015	0.000 ***	-0.018	0.000 ***	-0.018	0.000 ***	-0.018	0.000 ***	-0.014	0.000 ***	-0.016	0.000 ***
At3NofInjure	-0.380	0.000 ***	-0.484	0.000 ***	-0.377	0.000 ***	-0.348	0.000 ***	-0.375	0.000 ***	-0.376	0.000 ***	-0.395	0.000 ***	-0.339	0.000 ***
At4Landscape	0.259	0.000 ***	-0.024	0.840	0.276	0.000 ***	0.280	0.000 ***	0.274	0.000 ***	0.272	0.000 ***	0.172	0.001 ***	0.298	0.000 ***
At5Econ000yen	-0.015	0.000 ***	-0.009	0.000 ***	-0.013	0.000 ***	-0.014	0.000 ***	-0.017	0.004 ***	-0.014	0.000 ***	-0.001	0.750	-0.013	0.000 ***
CardNo			-1.124	0.000 ***												
At1Year:CardNo			0.001	0.460												
At2TD:CardNo			-0.002	0.130												
At3NofInjure:CardNo			0.136	0.000 ***												
At4Landscape:CardNo			0.156	0.001 ***												
At5Econ000yen:CardNo			-0.005	0.002 ***												
AorB					0.161	0.130										
At1Year:AorB					0.000	0.910										
At2TD:AorB					-0.005	0.077 *										
At3NofInjure:AorB					-0.006	0.750										
At4Landscape:AorB					-0.032	0.440										
At5Econ000yen:AorB					-0.005	0.160										
pd							0.073	0.500								
At1Year:pd							0.001	0.270								
At2TD:pd							-0.000	0.970								
At3NofInjure:pd							-0.067	0.000 ***								
At4Landscape:pd							-0.041	0.340								
At5Econ000yen:pd							-0.001	0.740								
descendants									-0.015	0.930						
At1Year:descendants									0.001	0.600						
At2TD:descendants									0.001	0.870						
At3NofInjure:descendants									-0.006	0.820						
At4Landscape:descendants									-0.016	0.800						
At5Econ000yen:descendants									0.003	0.670						
property											0.105	0.390				
At1Year:property											0.000	0.840				
At2TD:property											0.001	0.850				
At3NofInjure:property											-0.017	0.430				
At4Landscape:property											-0.049	0.310				
At5Econ000yen:property											-0.005	0.210				
lifexpct													-0.002	0.670		
At1Year:lifexpct													-0.000	0.690		
At2TD:lifexpct													-0.000	0.330		
At3NofInjure:lifexpct													0.000	0.520		
At4Landscape:lifexpct													0.003	0.071 *		
At5Econ000yen:lifexpct													-0.000	0.000 ***		
live															-1.394	0.000 ***
At1Year:live															0.041	0.000 ***
At2TD:live															0.003	0.310
At3NofInjure:live															0.054	0.004 ***
At4Landscape:live															-0.012	0.790
At5Econ000yen:live															-0.004	0.120
Likelihood ratio test	3,040		5,763		3,046		3,056		3,041		3,044		3,058		3,898	
p	0.000		0.000		0.000		0.000		0.000		0.000		0.000		0.000	

9.3.6.1.2 Model 2

Model 2 splits the timing into 2025, 2040, 2055 and 2100 to establish the gradation of preferences among the timings for development and management. Hypothetically, the closer the time is, the more preferable is development and management, and accordingly, the coefficients for the closer years should be shown to be positive and larger, however, the results do not support this hypothesis.

The results for Model 2 show that the timings for 2040 and 2055 are statistically significant, but the timings for 2025 and 2100 are not statistically significant. This is most probably the result of the irrationality of respondents and is caused by their different expected life spans.

Table 68 Conditional logit regression analysis results for Model 2 on public facilities

	Basic Model 2 Group															
Variables	Basic Model 2-2		Basic Model 2-CardNo		Basic Model 2-AorB		Basic Model 2-pd		Basic Model 2-dscndnts		Basic Model 2-property		Basic Model 2-lifexpct		Basic Model 2-live	
	coef	p	coef	p	coef	p	coef	p	coef	p	coef	p	coef	p	coef	p
At1Y2025	−0.022	0.700	−0.434	0.070 *	0.008	0.910	−0.035	0.640	0.131	0.340	−0.049	0.430	0.071	0.560	−1.639	0.340
At1Y2040	0.977	0.000 ***	1.163	0.000 ***	0.973	0.000 ***	0.984	0.000 ***	1.055	0.000 ***	0.953	0.000 ***	0.990	0.000 ***	−0.751	0.660
At1Y2055	−0.163	0.004 ***	−0.381	0.120	−0.252	0.001 ***	−0.182	0.014 **	−0.044	0.760	−0.177	0.005 ***	−0.196	0.120	−1.901	0.260
At1Y2100	−0.085	0.130	−0.082	0.130	−0.085	0.120	−0.085	0.120	−0.083	0.130	−0.084	0.130	−0.083	0.130	−1.797	0.290
At2TD	−0.012	0.000 ***	−0.000	0.960	−0.009	0.000 ***	−0.011	0.000 ***	−0.013	0.001 ***	−0.011	0.000 ***	−0.007	0.045 **	−0.013	0.000 ***
At3NofInjure	−0.237	0.000 ***	−0.185	0.000 ***	−0.236	0.000 ***	−0.211	0.000 ***	−0.230	0.000 ***	−0.235	0.000 ***	−0.244	0.000 ***	−0.266	0.000 ***
At4Landscape	0.320	0.000 ***	0.123	0.310	0.335	0.000 ***	0.343	0.000 ***	0.356	0.000 ***	0.337	0.000 ***	0.214	0.000 ***	0.318	0.000 ***
At5Econ000yen	−0.015	0.000 ***	−0.010	0.000 ***	−0.013	0.000 ***	−0.015	0.000 ***	−0.019	0.002 ***	−0.014	0.000 ***	−0.002	0.600	−0.014	0.000 ***
CardNo			−0.520	0.000 ***												
At1Y2025:CardNo			0.168	0.077 *												
At1Y2040:CardNo			−0.463	0.000 ***												
At1Y2055:CardNo			0.093	0.350												
At2TD:CardNo			−0.003	0.042 **												
At3NofInjure:CardNo			0.020	0.270												
At4Landscape:CardNo			0.095	0.051 *												
At5Econ000yen:CardNo			−0.005	0.003 ***												
AorB					0.148	0.230										
At1Y2025:AorB					−0.062	0.510										
At1Y2040:AorB					0.008	0.910										
At1Y2055:AorB					0.172	0.081 *										
At2TD:AorB					−0.005	0.085 *										
At3NofInjure:AorB					−0.002	0.900										
At4Landscape:AorB					−0.031	0.500										
At5Econ000yen:AorB					−0.005	0.130										
pd							0.149	0.230								
At1Y2025:pd							0.023	0.810								
At1Y2040:pd							−0.018	0.780								
At1Y2055:pd							0.037	0.700								
At2TD:pd							−0.001	0.640								
At3NofInjure:pd							−0.054	0.004 ***								
At4Landscape:pd							−0.047	0.300								
At5Econ000yen:pd							−0.001	0.880								
descendants									0.141	0.470						
At1Y2025:descendants									−0.173	0.230						
At1Y2040:descendants									−0.087	0.390						
At1Y2055:descendants									−0.134	0.370						
At2TD:descendants									0.002	0.640						
At3NofInjure:descendants									−0.008	0.770						
At4Landscape:descendants									−0.042	0.550						
At5Econ000yen:descendants									0.004	0.550						
property											0.094	0.500				
At1Y2025:property											0.108	0.320				
At1Y2040:property											0.096	0.190				
At1Y2055:property											0.056	0.620				
At2TD:property											0.000	0.940				
At3NofInjure:property											−0.008	0.700				
At4Landscape:property											−0.068	0.190				
At5Econ000yen:property											−0.007	0.130				
lifexpct													−0.003	0.500		
At1Y2025:lifexpct													−0.003	0.410		
At1Y2040:lifexpct													−0.000	0.870		
At1Y2055:lifexpct													0.001	0.760		
At2TD:lifexpct													−0.000	0.260		
At3NofInjure:lifexpct													0.000	0.760		
At4Landscape:lifexpct													0.003	0.043 **		
At5Econ000yen:lifexpct													−0.000	0.001 ***		
live															−1.806	0.290
At1Y2025:live															1.607	0.340
At1Y2040:live															1.742	0.310
At1Y2055:live															1.825	0.280
At2TD:live															0.002	0.390
At3NofInjure:live															0.057	0.002 ***
At4Landscape:live															0.005	0.910
At5Econ000yen:live															−0.004	0.110
Likelihood ratio test	4,771		5,913		4,782		4,782		4,774		4,778		4,791		4,788	
p	0.000		0.000		0.000		0.000		0.000		0.000		0.000		0.000	

When checking the results of the interaction effect with the “live” variable, this hypothesis cannot, unfortunately, be accepted because there are no statistically significant estimated timings. It suggests that respondents are not concerned about timing, but only mind if they are still alive or not.

9.3.6.2 Water supply and waste water management

The results of the conditional logit regression analysis for water and waste water management are shown in Table 69 and Table 70.

9.3.6.2.1 Model 1

The results for the timing of development in Model 1 for water and waste water management are small and it means that respondents do not want to develop infrastructure earlier than other aspects. In terms of the engineering aspects, respondents do not seriously mind the number of accidents (water supply interruption), but they do care about both the social aspect and the environmental aspect of water quality in water and waste water management. In contrast to the other two infrastructure types, the social aspect and the environmental aspect of water quality directly affect the respondents’ health but accidents in water supply and waste water management are linked only to the service level.

In terms of status quo bias, the variable of “CardNo” is statistically significant but at the 10% level. Only the interaction effect on the economic aspect can be estimated, but the other variables are not significant. The effect of this bias could therefore be ignored.

Population decline, which is the main concern of this study, does not influence the preferences of the respondents. There is very little difference in the likelihood ratio between Model 1-1 and the Model 1-pd, which means that the variable “pd” does not result in any statistically significant difference and population decline is not a major factor in the preferences of respondents.

Table 69 Conditional logit regression analysis results for Model 1 for water and waste water management

Water	Basic Model 1 Group													
Variables	Basic Model 1-1		Basic Model 1-CardNo		Basic Model 1-pd		Basic Model 1-dscndnts		Basic Model 1-property		Basic Model 1-lifexpct		Basic Model 1-live	
	coef	p	coef	p	coef	p	coef	p	coef	p	coef	p	coef	p
At1Year	-0.003	0.000 ***	-0.004	0.310	-0.004	0.000 ***	-0.003	0.170	-0.003	0.000 ***	-0.004	0.016 **	-0.012	0.000 ***
At2Regulation	-0.274	0.000 ***	-0.082	0.620	-0.278	0.000 ***	-0.157	0.062 *	-0.254	0.000 ***	-0.321	0.000 ***	-0.308	0.000 ***
At3NofAccidents	-0.087	0.000 ***	-0.069	0.000 ***	-0.087	0.000 ***	-0.102	0.000 ***	-0.084	0.000 ***	-0.088	0.000 ***	-0.087	0.000 ***
At4EnvQuality	0.342	0.000 ***	0.198	0.230	0.390	0.000 ***	0.398	0.000 ***	0.361	0.000 ***	0.372	0.000 ***	0.407	0.000 ***
At5Econ000yen	-0.077	0.000 ***	-0.051	0.000 ***	-0.087	0.000 ***	-0.086	0.000 ***	-0.078	0.000 ***	-0.035	0.005 ***	-0.075	0.000 ***
CardNo			-0.330	0.086 *										
At1Year:CardNo			0.001	0.450										
At2TD:CardNo			-0.099	0.130										
At3NofInjure:CardNo			-0.000	1.000										
At4Landscape:CardNo			0.086	0.190										
At5Econ000yen:CardNo			-0.020	0.000 ***										
pd					NA	NA								
At1Year:pd					0.001	0.310								
At2TD:pd					0.005	0.930								
At3NofInjure:pd					-0.001	0.830								
At4Landscape:pd					-0.092	0.120								
At5Econ000yen:pd					0.020	0.045 **								
descendants							NA	NA						
At1Year:descendants							-0.001	0.710						
At2TD:descendants							-0.135	0.130						
At3NofInjure:descendants							0.016	0.110						
At4Landscape:descendants							-0.064	0.480						
At5Econ000yen:descendants							0.010	0.540						
property									NA	NA				
At1Year:property									-0.002	0.350				
At2TD:property									-0.083	0.220				
At3NofInjure:property									-0.013	0.088 *				
At4Landscape:property									-0.071	0.300				
At5Econ000yen:property									0.005	0.640				
lifexpct											NA	NA		
At1Year:lifexpct											0.000	0.610		
At2TD:lifexpct											0.001	0.490		
At3NofInjure:lifexpct											-0.000	0.990		
At4Landscape:lifexpct											-0.001	0.680		
At5Econ000yen:lifexpct											-0.001	0.000 ***		
live													-0.812	0.000 ***
At1Year:live													0.029	0.000 ***
At2TD:live													0.021	0.730
At3NofInjure:live													0.011	0.087 *
At4Landscape:live													-0.066	0.290
At5Econ000yen:live													-0.015	0.024 **
Likelihood ratio test	1,378		2,064		1,385		1,384		1,385		1,393		1,629	
p	0.000		0.000		0.000		0.000		0.000		0.000		0.000	

Three of the four variables on intergenerational decision-making, namely “descendants”, “property”, and “lifexpct” also do not make any difference to the preference of respondents. Only the variable “live” in the water and waste water management sector is a statistically significantly influence according to the preference of respondents, but the sign on “At1Year*live” is positive and this means that the later the development and management is, the more preferable it is. Accordingly, the respondents did not eagerly promote infrastructure development and management activity with payment during their lives, but would prefer to postpone these activities until after their death.

9.3.6.2.2 Model 2

Model 2 splits the timing of the development and management of water and waste water management infrastructure into 2025, 2040, 2055 and 2100, but only 2040 is a statistically significant timing. As mentioned before, 2040 is a benchmark year and is affected by status quo bias. The variable “CardNo” is too large to be significant; therefore, the order of choice card in the choice set does not indicate any bias in general.

The variables “live” are not statistically significant in this case. This means that respondents did not mind the exact timing of development and management, but were only concerned about their own lives and other aspects of sustainability.

The results for the other variables of population decline and three variables on intergenerational decision-making, namely, “descendants”, “property”, and “lifexpct” are almost the same as the results in Model 1 for the water and waste water management sector. This means that they are invalid in terms of significant differences in the preferences of respondents in the four aspects and the timing of development and management.

In summary, similar results to those for public facilities can be observed in the water and waste water management sector.

Table 70 Conditional logit regression analysis results for Model 2 for water and waste water management

Water	Basic Model 2 Group													
Variables	Basic Model 2-2		Basic Model 2-CardNo		Basic Model 2-pd		Basic Model 2-dscndnts		Basic Model 2-property		Basic Model 2-lifexpct		Basic Model 2-live	
	coef	p	coef	p	coef	p	coef	p	coef	p	coef	p	coef	p
At1Y2025	0.109	0.140	0.219	0.560	0.031	0.770	0.161	0.470	0.094	0.270	-0.279	0.095 *	11.873	0.980
At1Y2040	0.638	0.000 ***	0.548	0.043 **	0.615	0.000 ***	0.823	0.000 ***	0.634	0.000 ***	0.543	0.000 ***	12.462	0.980
At1Y2055	-0.036	0.630	0.287	0.450	-0.109	0.310	0.119	0.590	-0.067	0.440	-0.379	0.025 **	11.740	0.980
At1Y2100	-0.034	0.650	-0.074	0.840	-0.105	0.320	0.128	0.570	0.003	0.970	-0.031	0.680	11.776	0.980
At2TD	-0.308	0.000 ***	-0.119	0.470	-0.307	0.000 ***	-0.165	0.065 *	-0.288	0.000 ***	-0.378	0.000 ***	-0.329	0.000 ***
At3NofInjure	-0.076	0.000 ***	-0.055	0.002 ***	-0.075	0.000 ***	-0.090	0.000 ***	-0.072	0.000 ***	-0.075	0.000 ***	-0.081	0.000 ***
At4Landscape	0.390	0.000 ***	0.258	0.120	0.436	0.000 ***	0.456	0.000 ***	0.416	0.000 ***	0.452	0.000 ***	0.434	0.000 ***
At5Econ000yen	-0.085	0.000 ***	-0.052	0.000 ***	-0.096	0.000 ***	-0.097	0.000 ***	-0.086	0.000 ***	-0.039	0.003 ***	-0.078	0.000 ***
CardNo			-0.068	0.750										
At1Y2025:CardNo			-0.051	0.730										
At1Y2040:CardNo			-0.243	0.031 **										
At1Y2055:CardNo			-0.135	0.380										
At1Y2100:CardNo			0.013	0.930										
At2TD:CardNo			-0.084	0.210										
At3NofInjure:CardNo			-0.005	0.440										
At4Landscape:CardNo			0.062	0.350										
At5Econ000yen:CardNo			-0.019	0.000 ***										
pd					NA	NA								
At1Y2025:pd					0.148	0.320								
At1Y2040:pd					0.042	0.710								
At1Y2055:pd					0.140	0.350								
At1Y2100:pd					0.135	0.370								
At2TD:pd					-0.003	0.970								
At3NofInjure:pd					-0.002	0.740								
At4Landscape:pd					-0.089	0.160								
At5Econ000yen:pd					0.023	0.033 **								
descendants							NA	NA						
At1Y2025:descendants							-0.058	0.810						
At1Y2040:descendants							-0.207	0.250						
At1Y2055:descendants							-0.176	0.460						
At1Y2100:descendants							-0.182	0.440						
At2TD:descendants							-0.164	0.086 *						
At3NofInjure:descendants							0.016	0.130						
At4Landscape:descendants							-0.075	0.440						
At5Econ000yen:descendants							0.014	0.440						
property									NA	NA				
At1Y2025:property									0.059	0.730				
At1Y2040:property									0.022	0.870				
At1Y2055:property									0.116	0.500				
At1Y2100:property									-0.142	0.410				
At2TD:property									-0.078	0.280				
At3NofInjure:property									-0.014	0.080 *				
At4Landscape:property									-0.096	0.180				
At5Econ000yen:property									0.003	0.780				
lifexpct											NA	NA		
At1Y2025:lifexpct											0.012	0.009 ***		
At1Y2040:lifexpct											0.003	0.290		
At1Y2055:lifexpct											0.011	0.022 **		
At2TD:lifexpct											0.002	0.340		
At3NofInjure:lifexpct											-0.000	0.880		
At4Landscape:lifexpct											-0.002	0.410		
At5Econ000yen:lifexpct											-0.002	0.000 ***		
live													11.947	0.980
At1Y2025:live													-11.761	0.980
At1Y2040:live													-11.849	0.980
At1Y2055:live													-11.668	0.980
At2TD:live													0.041	0.520
At3NofInjure:live													0.010	0.120
At4Landscape:live													-0.081	0.210
At5Econ000yen:live													-0.015	0.025 **
Likelihood ratio test	1,779		2,077		1,787		1,788		1,788		1,807		1,792	
p	0.000		0.000		0.000		0.000		0.000		0.000		0.000	

9.3.6.3 Roads

The results of the conditional logit regression analysis for water and waste water management are shown in Table 71 and Table 72.

9.3.6.3.1 Model 1

The social and the economic aspects received lower evaluations than the other two aspects, while the engineering aspect (number of accidents) resulted in the highest score, almost 100 times as great as the number for the social and economic aspects.

Road development is often criticised, but the result suggests that the development of road accident countermeasures and environmental improvements is probably supported by the users of roads rather than the expansion of the length and width of roads.

In terms of status quo bias, the variable “CardNo” was not found to be valid for the road sector or for the other two sectors. In addition, the interaction effects on “pd”, “descendants”, “property” and “lifexpct” do not result in a significant influence on the respondent preferences for the four aspects and the timing of development and maintenance matters.

On the other hand, the interaction effect of “live” is significant. The respondents also decided that later investment is better within their lives, as well as in the other two sectors, but the preference for other aspects is not influenced by the expectation of their lives.

Table 71 Conditional logit regression analysis results for Model 1 for road

Road	Basic Model 1 Group													
Variables	Basic Model 1-1		Basic Model 1-CardNo		Basic Model 1-pd		Basic Model 1-dscndnts		Basic Model 1-property		Basic Model 1-lifexpct		Basic Model 1-live	
	coef	p	coef	p	coef	p	coef	p	coef	p	coef	p	coef	p
At1Year	-0.002	0.006 ***	0.001	0.690	-0.002	0.082 *	-0.001	0.590	-0.002	0.024 **	-0.003	0.130	-0.009	0.000 ***
At2TD	-0.013	0.000 ***	-0.009	0.000 ***	-0.011	0.000 ***	-0.017	0.000 ***	-0.014	0.000 ***	-0.011	0.000 ***	-0.011	0.000 ***
At3NofAccidents	-1.481	0.000 ***	-0.979	0.001 ***	-1.509	0.000 ***	-1.640	0.000 ***	-1.478	0.000 ***	-1.150	0.000 ***	-1.304	0.000 ***
At4EnvRecov	0.172	0.000 ***	-0.007	0.960	0.201	0.000 ***	0.174	0.046 **	0.153	0.000 ***	0.204	0.005 ***	0.141	0.001 ***
At5Econ	-0.011	0.000 ***	-0.006	0.037 **	-0.012	0.000 ***	-0.011	0.000 ***	-0.011	0.000 ***	-0.011	0.000 ***	-0.012	0.000 ***
CardNo			-0.166	0.410										
At1Year:CardNo			-0.001	0.710										
At2TD:CardNo			-0.000	0.670										
At3NofAccidents:CardNo			-0.022	0.850										
At4EnvRecov:CardNo			0.072	0.270										
At5Econ:CardNo			-0.003	0.010 **										
pd					NA	NA								
At1Year:pd					-0.000	0.780								
At2TD:pd					-0.005	0.020 **								
At3NofAccidents:pd					0.057	0.640								
At4EnvRecov:pd					-0.054	0.360								
At5Econ:pd					0.001	0.500								
descendants							NA	NA						
At1Year:descendants							-0.001	0.670						
At2TD:descendants							0.005	0.210						
At3NofAccidents:descendants							0.178	0.350						
At4EnvRecov:descendants							-0.001	0.990						
At5Econ:descendants							0.000	0.970						
property									NA	NA				
At1Year:property									-0.000	0.820				
At2TD:property									0.003	0.230				
At3NofAccidents:property									-0.009	0.950				
At4EnvRecov:property									0.074	0.270				
At5Econ:property									0.000	0.840				
lifexpct											NA	NA		
At1Year:lifexpct											0.000	0.680		
At2TD:lifexpct											-0.000	0.340		
At3NofAccidents:lifexpct											-0.010	0.015 **		
At4EnvRecov:lifexpct											-0.001	0.650		
At5Econ:lifexpct											-0.000	0.830		
live													-0.938	0.000 ***
At1Year:live													0.027	0.000 ***
At2TD:live													-0.001	0.360
At3NofAccidents:live													-0.010	0.930
At4EnvRecov:live													0.056	0.360
At5Econ:live													0.000	0.890
Likelihood ratio test	1,541		2,038		1,549		1,544		1,544		1,549		1,741	
p	0.000		0.000		0.000		0.000		0.000		0.000		0.000	

9.3.6.3.2 Model 2

Model 2 splits the timing of development and management as a series of dummy variables, 2025, 2040, 2055 and 2100, as with the other two sectors.

The results are almost the same as those for the other two sectors, but the general tendency is that they are more unstable. This means that the p-values of estimated results are much less than for the other two sectors. As a result, there are no significant variables in the Model 2-live.

Table 72 Conditional logit regression analysis results for Model 2 for road

Road	Basic Model 2 Group													
Variables	Basic Model 2-2		Basic Model 2-CardNo		Basic Model 2-pd		Basic Model 2-dscndnts		Basic Model 2-property		Basic Model 2-lifexpct		Basic Model 2-live	
	coef	p	coef	p	coef	p	coef	p	coef	p	coef	p	coef	p
At1Y2025	0.093	0.210	0.194	0.600	0.123	0.250	0.109	0.210	0.208	0.340	0.028	0.880	-13.600	0.990
At1Y2040	0.635	0.000 ***	0.563	0.039 **	0.680	0.000 ***	0.629	0.000 ***	0.700	0.000 ***	0.490	0.000 ***	-13.200	0.990
At1Y2055	0.025	0.740	-0.182	0.630	-0.087	0.420	-0.007	0.930	0.143	0.530	-0.031	0.870	-13.800	0.990
At1Y2100	0.078	0.290	0.496	0.180	0.153	0.150	0.086	0.320	0.216	0.330	-0.052	0.770	-13.700	0.990
At2TD	-0.010	0.000 ***	-0.008	0.000 ***	-0.008	0.000 ***	-0.011	0.000 ***	-0.014	0.000 ***	-0.008	0.001 ***	-0.010	0.000 ***
At3NofAccidents	-1.139	0.000 ***	-0.486	0.130	-1.139	0.000 ***	-1.142	0.000 ***	-1.320	0.000 ***	-0.858	0.000 ***	-1.160	0.000 ***
At4EnvRecov	0.170	0.000 ***	0.017	0.920	0.202	0.000 ***	0.144	0.000 ***	0.170	0.061 *	0.211	0.006 ***	0.142	0.001 ***
At5Econ	-0.012	0.000 ***	-0.007	0.009 ***	-0.012	0.000 ***	-0.012	0.000 ***	-0.012	0.000 ***	-0.012	0.000 ***	-0.012	0.000 ***
CardNo			-0.033	0.880										
At1Y2025:CardNo			-0.042	0.780										
At1Y2040:CardNo			-0.168	0.140										
At1Y2055:CardNo			0.082	0.580										
At1Y2100:CardNo			-0.172	0.250										
At2TD:CardNo			-0.000	0.610										
At3NofAccidents:CardNo			-0.210	0.110										
At4EnvRecov:CardNo			0.062	0.340										
At5Econ:CardNo			-0.002	0.049 **										
pd					NA	NA								
At1Y2025:pd					-0.054	0.720								
At1Y2040:pd					-0.089	0.430								
At1Y2055:pd					0.221	0.140								
At1Y2100:pd					-0.147	0.330								
At2TD:pd					-0.005	0.026 **								
At3NofAccidents:pd					0.001	0.990								
At4EnvRecov:pd					-0.059	0.350								
At5Econ:pd					0.001	0.400								
property							NA	NA						
At1Y2025:property							-0.061	0.720						
At1Y2040:property							0.028	0.830						
At1Y2055:property							0.130	0.450						
At1Y2100:property							-0.028	0.870						
At2TD:property							0.003	0.240						
At3NofAccidents:property							0.016	0.910						
At4EnvRecov:property							0.097	0.160						
At5Econ:property							-0.000	0.910						
descendants									NA	NA				
At1Y2025:descendants									-0.131	0.570				
At1Y2040:descendants									-0.073	0.690				
At1Y2055:descendants									-0.132	0.580				
At1Y2100:descendants									-0.156	0.510				
At2TD:descendants									0.004	0.350				
At3NofAccidents:descendants									0.208	0.290				
At4EnvRecov:descendants									0.000	1.000				
At5Econ:descendants									-0.000	0.990				
lifexpct											NA	NA		
At1Y2025:lifexpct											0.002	0.700		
At1Y2040:lifexpct											0.004	0.250		
At1Y2055:lifexpct											0.002	0.720		
At1Y2100:lifexpct											0.004	0.420		
At2TD:lifexpct											-0.000	0.400		
At3NofAccidents:lifexpct											-0.009	0.046 **		
At4EnvRecov:lifexpct											-0.001	0.560		
At5Econ:lifexpct											-0.000	0.950		
live													-13.900	0.990
At1Y2025:live													13.700	0.990
At1Y2040:live													13.900	0.990
At1Y2055:live													13.900	0.990
At2TD:live													-0.001	0.520
At3NofAccidents:live													0.030	0.810
At4EnvRecov:live													0.056	0.370
At5Econ:live													0.000	0.840
Likelihood ratio test	1,882		2,057		1,897		1,887		1,885		1,892		1,888	
p														

9.3.7 *MARGINAL WILLINGNESS TO PAY*

This section estimates the marginal willingness to pay (MWTP) for each infrastructure type (see results in Figure 100).

The MWTP on the timing of each infrastructure type is generally smaller than for other aspects. The MWTPs on the engineering aspect in public facilities and roads are the greatest among the aspects: over 25,000 Japanese Yen (JPY) per unit. This means that respondents evaluated the risk of accidents more seriously.

The environmental aspect seems to be the second most important aspect for respondents. The top evaluation was for water and waste water management and the second largest evaluation was given for public facilities and roads. The values of MWTP are over 4,500 JPY per level while social aspects such as time distance to public facilities and roads are given as relatively smaller values.

The MWTP for timing is rather smaller than the values for other aspects. Less than 500 JPY/year would be paid by each person for promoting infrastructure development and management project. It can be concluded that such a small number suggests that the respondents are already satisfied with the development and management situation for infrastructure in Japan and did not feel any need to change the infrastructure situation at all.

Public facilities		
	MWTP	Unit
At1Year	303.8	JPY/(person・year)
At2TD	1,209.8	JPY/(person・minutes)
At3NofInjure	25,916.9	JPY/(person・injured person)
At4Landscape	17,656.0	JPY/(person・landscape change)

Water and waste water management		
	MWTP	Unit
At1Year	45.2	JPY/(person・year)
At2Regulation	3,581.3	JPY/(person・water quality change)
At3NofAccidents	1,141.5	JPY/(person・times)
At4EnvQuality	4,467.2	JPY/(person・river water quality change)

Road		
	MWTP	Unit
At1Year	176.6	JPY/(person・year)
At2TD	1,141.8	JPY/(person・minutes)
At3NofAccidents	132,103.5	JPY/(person・injured person)
At4EnvRecov	15,380.0	JPY/(person・landscape change)

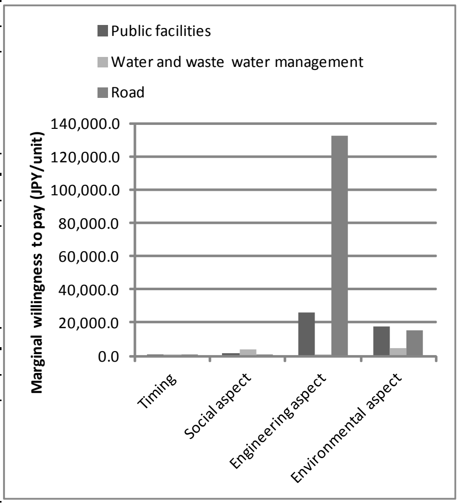


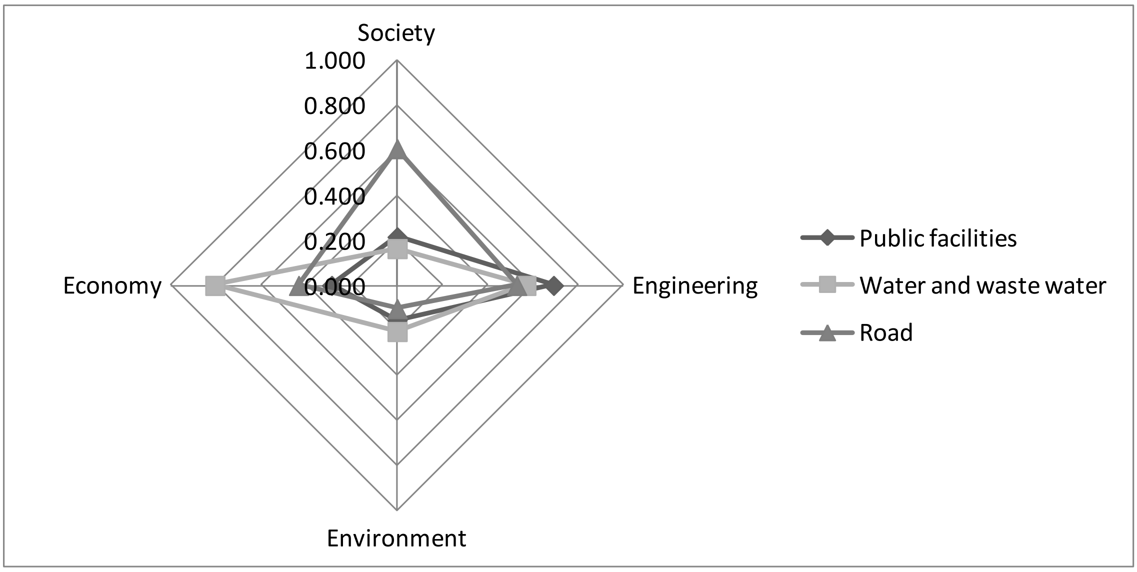
Figure 100 Marginal willingness to pay for the three types of infrastructure

9.4 Discussion and analysis

The differences between infrastructure types, population decline and the rationality of intergenerational decision-making are discussed in this section. Firstly, the differences between the types of infrastructure are discussed and then, particularly, the differences of the estimation results for population decline and intergenerational decision-making issues are discussed.

9.4.1 Differences between infrastructure types

The standardised coefficients tell us the degree to which respondents consider aspects of infrastructure sustainability when selecting from set choices. A summary of the standardised coefficients is shown in Figure 101.



Standard coefficients	Public facilities	Water and waste water	Road
Timing of developments	0.102	0.077	0.051
Society	0.215	0.163	0.606
Engineering	0.692	0.570	0.529
Environment	0.154	0.204	0.103
Economy	0.290	0.807	0.436

Coefficients	Public facilities	Water and waste water	Road
Timing of developments	0.004	0.003	0.002
Society	0.018	0.274	0.013
Engineering	0.380	0.087	1.481
Environment	0.259	0.342	0.172
Economy	0.015	0.077	0.011

Figure 101 Comparison of standardised coefficients among aspects in each infrastructure type

When respondents select their choice of public facilities, they are more concerned with the engineering aspects and the society and economy aspects follow. In terms of water and waste water management, the aspect about which they are most concerned is economy and then the engineering aspect. On the other hand, in the road sector, respondents were more concerned with society (time distance to the destination) but the engineering and economy aspects are also concerns.

This suggests that citizens will be concerned with the different aspects of sustainable infrastructure development and management in accordance with the type of infrastructure when they face the critical situation of having to decide to downgrade the infrastructure service provision in the municipality where they live. Thus, it can also be suggested that infrastructure management has to develop individual strategies to focus on certain aspects so as to negotiate and persuade residents to reorganise the spatial configuration of infrastructures.

9.4.2 WEAK SUSTAINABILITY VS. STRONG SUSTAINABILITY

According to the definition of weak sustainability, whereby “environmental quality can be traded against economic gain” (Bell and Morse, 2008: p.14), the sustainability of infrastructure development and management can be considered to be weak sustainability in the economic sense, because infrastructure is artificial capital and it needs artificial care involving the consumption of financial resources. The study’s results for the roads, however, provides an interesting indication that respondents are concerned with a specific aspect, namely, safety issues in the engineering aspect, where there is a strong willingness to pay. Of course, the relative magnitude of explanatory variables influences the magnitude of coefficients, and the absolute values of the coefficients do not necessarily correspond to the magnitude of the preferences shown by the respondents, but it suggests that we should take into consideration the possibility of an extreme preference for one of the four aspects of the sustainability of infrastructure development and management.

This can be considered similar to the story of genuine saving requiring strong sustainability, namely, “no trade-off between economic gain and environmental quality is acceptable” (Bell and Morse, 2008: p.14). The safety issue seems to be considered as the absolute norm by respondents in Japan. It means that a kind of infrastructure sustainability should be understood as strong sustainability even though the sustainability of infrastructure management will be constrained by the limitation of financial resources.

9.4.3 Analysis of Population Decline

The main concern of this study was the impact of population decline on infrastructure development and management. This study took the users' perspective and has collected and analysed the data on preferences for the policy of infrastructure development and management from the users' viewpoint. No interaction effects could be observed from the results of the estimation for all three types of infrastructure, however. Accordingly, from the users' viewpoint, there is no difference in preference between depopulating areas and non-depopulating areas for the three types of infrastructure. Infrastructure managers should not therefore mind whether the areas are depopulating or not, and should concentrate on conducting good management of infrastructure regardless of depopulation.

9.4.4 Analysis of Intergenerational Decision Making

For intergenerational decision-making, this study has provided four variables. The summary of results is in Table 73.

Table 73 Summary of estimate results for variables related to intergenerational decision-making

Model 1: Variables	dscndnts	property	lifexpct	live
Public facilities				✓✓✓
Water and waste water				✓✓✓
Road				✓✓✓

Model 2: Variables	dscndnts	property	lifexpct	live
Public facilities				
Water and waste water				
Road				

Note: ✓:10% significance, ✓✓: 5% significance, ✓✓✓: 1% significance.

Unfortunately, none of the variables for any infrastructure type in either model, except "live" in Model 1, are statistically significant. This means that Barro's theory – the overlapping generational model for discussing infrastructure development – is not expected to be satisfied with its premises that people should take their descendants and the succession of properties into consideration when they decide their household expenditure in accordance with issuing public debts. This result also rejects the second model. The second model is not satisfied with the contextual condition of population decline, and is also rejected in regards to the altruistic condition of its model.

According to the results of this study, respondents have not undertaken decision-making altruistically with consideration to further generations. This means that the deficits in government budgets will not be neutral between generations. In addition, as described previously, respondents only optimise their preferences within their own lives. This means that the elderly easily make decisions without considering long-term rationality.

In the preliminary stage of population decline, ageing will take place: most developed countries have a baby-boomer generation and their populations are getting increasingly older. The politicians, who are official decision-makers for developing infrastructure with a long durable life, follow the opinions of the elderly in order to secure their election. This means that politicians will probably tend to choose short-sighted policies for infrastructure development and management. Simultaneously, as the results of this study have shown, the young would also like to postpone the vast public expenditure required to replace and maintain infrastructure as long as they can, although the infrastructure is getting older and gradually deteriorating.

Infrastructure development is often financed by ten year Treasury bonds (T-bonds), and the T-bonds are often reissued in order to defer the actual reimbursement, depending on the economic situation. Based on the analytical results of this study, infrastructure developments and management involving large expenditure will be surely postponed. This means that the current generation will place their burden on a future generation, which will involve both an increased technical risk of accidents and injuries owing to the physical deterioration of the infrastructure as a result of insufficient maintenance, and an increased financial burden owing to delayed maintenance resulting in ultimate replacement anyway, and at any cost.

9.4.5 Discussion of infrastructure sustainability

This expected situation is, indeed the situation assumed by Samuelson. As soon as people can consume the infrastructure service provision, it will maximise total welfare, but such an optimised situation is not, of course, a sustainable infrastructure service provision. If the real interest rate could be controlled as negative, or the infrastructure managers reduce maintenance costs, it could mitigate the rapid and apparent negative impacts on infrastructure management, but the per capita financial burden problem will be realised when the replacement takes place, sooner or later. Accordingly, appropriate technical countermeasures to reduce the replacement cost or prolong the life expectancy of the physical infrastructure are also required.

In addition, according to this study, a different concern/priority for the four aspects of infrastructure service provision was also observed. When infrastructure managers develop countermeasures, they will also have to prioritise some aspects depending on the types of infrastructure in order to balance the four aspects. This means that in terms of infrastructure sustainability, balancing the four aspects doesn't mean dealing with the four aspects equally. This discussion is very technical and considering the irrationality of inter-temporal decision making by the citizens, the democratic decision making process may not be suitable.

Thus, in order to bring about infrastructure sustainability resulting in the realisation of a sustainable society, an appropriate consensus-making process should be developed based on the proper timing of infrastructure development and management and on appropriate technical advice; otherwise, the wise-monarch approach may be required. These points are related to proposed countermeasures both in this study and in previous studies. This topic will therefore be discussed in the next chapter.

9.5 Concluding remarks

This chapter has examined public preferences for the sustainability of infrastructure by simultaneously evaluating the four aspects of infrastructure sustainability – "society", "engineering", "environment" and "economy" – and estimating the marginal willingness to pay for the four aspects, considering the differences between depopulating and non-depopulating areas and the three types of infrastructure, point type, point-network type and network type using the choice modelling approach.

The study has demonstrated an approach towards the evaluation of the balance of the four aspects of the sustainability of infrastructure and the timing of development and management. This approach can be applied to the discussion of the sustainability of individual infrastructure managed by municipalities.

From this study, in the context of population decline, we could not identify any differences in the estimated coefficients for depopulating areas and non-depopulating areas, but we could find slight differences between three types of infrastructure. Much more interestingly, the main findings of this study provide evidence to cast doubt on the premises of Barro's overlapping generational model which is often applied in the discussion on intergenerational decision-making, in particular, on public debts. This result reveals the difficulties in the discussion of long-term intergenerational infrastructure development and management. As noted, these are the same types of issues as global warming, where researchers should promote discussion to help develop rational solutions which contribute to realising infrastructure sustainability in the long-term.

The points for further discussion are as follows:

First, very limited information on infrastructure development and management was given to the respondents in this study. The impact of giving richer information to respondents should be considered. If the amount and content of information is the key to appropriate decision-making we should develop good information transfer rules and systems when we discuss infrastructure sustainability. Sustainable development indicators for infrastructure may be one of the potential tools.

Second, the authority for decision-making should be carefully allocated. The budget for infrastructure development and management is often and easily cut in order to improve the fiscal situation. On the other hand, politicians often over-promise new developments in infrastructure to obtain more votes from the citizens. Technical engineers often tend to emphasise the technical aspect of infrastructure and over-maintain the infrastructure. As a result, it is difficult to find good managers of infrastructure who can take all these aspects into consideration. This suggests that we should educate high quality infrastructure managers who understand the social, technical, environmental and financial issues. These infrastructure managers should have the right to allocate the budget for infrastructure development and management projects. Once such an infrastructure manager is in charge of realising infrastructure sustainability, the reporting methods should also be developed to ensure accountability. The ideal would be something like the "wise governor".

Third, we should also develop solutions which do not need so many budgets. These may sometimes involve technical solutions, or sometimes social systems such as cooperation between users and managers. Traditionally, local people have responsibility for the development and management of their infrastructure in Japan. This is a kind of public private partnership, and several good examples can be found. Once people are involved in developing and managing infrastructure they may change their attitudes on infrastructure sustainability, since they can sustain their infrastructure more rationally.

In summary, this chapter proposes a method for evaluating public preferences for infrastructure sustainability. The problem of the irrationality of respondents on sustainable infrastructure development is a general issue not only in depopulating areas but also in non-depopulating areas and means that we should consider the impact on infrastructure of depopulation as a nationwide issue, and develop ways to ensure sustainable infrastructure development and management as soon as possible, and before depopulation becomes more severe.

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CHAPTER 10: DISCUSSION: POPULATION DECLINE, INFRASTRUCTURE AND SUSTAINABILITY-ISSUES, COUNTERMEASURES AND POLICY IMPLICATIONS-

10.1 INTRODUCTION

Seven years have passed since this study was started, during which time population decline in Japan has finally become apparent according to the basic resident register population statistics.

On the other hand, in response to recent abnormal weather and countermeasures for global warming, several studies of sustainable infrastructure development have been published (Sarte, 2010; Pearce, Ahn and HanmiGlobal, 2012; Martland, 2012). These have mainly been discussions about saving energy resources and how to finance infrastructure development and management, but have not pointed out the existence of a balance between multiple aspects and intergenerational equity regarding the sustainable development and management of infrastructure in the context of population decline.

As described in the introductory chapter of this study, the infrastructure consists of man-made capital and will not regenerate naturally without human intervention. On the other hand, once a certain amount of human and economic capital is invested, the infrastructure can be easily regenerated. In addition, the service provision (quality and quantity) of the infrastructure depends of how much financial burden the users can accept. This process may lead to ‘weak sustainability’ as regards infrastructure development and management.

In the previous chapters there have been discussions about what sustainable infrastructure development is and how it can be managed, along with some focus being placed on the impact of population decline on sustainable infrastructure development and management from the perspectives of both infrastructure managers’ perspectives and users. It may be expected that a two sided approach can carve out an outline of what sustainable infrastructure development and management can consist of in a depopulating society.

At the same time, when sustainable infrastructure development and management are threatened by population decline, human lives may be threatened by the deterioration of the infrastructure. Thus, it is necessary to analyze not only what will happen to the infrastructure in the case of population decline, but also it is essential to discuss what type of countermeasures could be useful in managing the issues and problems of infrastructure development and management resulting from population decline.

Throughout this study, countermeasures regarding the issues and impact of population decline on sustainable infrastructure development and management are not discussed sufficiently, but some research results will be introduced to provide some policy and project ideas for infrastructure managers. In this chapter, therefore, the considerable countermeasures and policy implications from this study and previous studies are aimed to combine and to develop the useful suggestions to infrastructure managers nowadays and in the future.

The structure of this chapter is as follows: section two outlines the framework of this chapter and explains the scope of the additional literature review for countermeasures regarding the relevant issues related to the impact of population decline on infrastructure management. In section three, there will be a summary of the previous chapters including the main results of the quantitative analysis. Section four explains the necessary countermeasures and also provides some idea on necessary viewpoints of management and monitoring to realize sustainable infrastructure development and management. Finally, a summary of this chapter, ideas for further research tasks and concluding remarks will be outlined in the conclusion.

10.2 Methodology

10.2.1 Framework of discussion

This chapter summarizes the discussion results and assumes the following framework in Figure 102. Here, a comparative study of the phenomena of impact occurrence between four aspects is presented, with some focus on intergenerational equity, and then countermeasures for each aspect, their repercussions for the other aspects, and the importance of a combination of countermeasures like cocktail therapy (multidrug therapy) will be discussed.

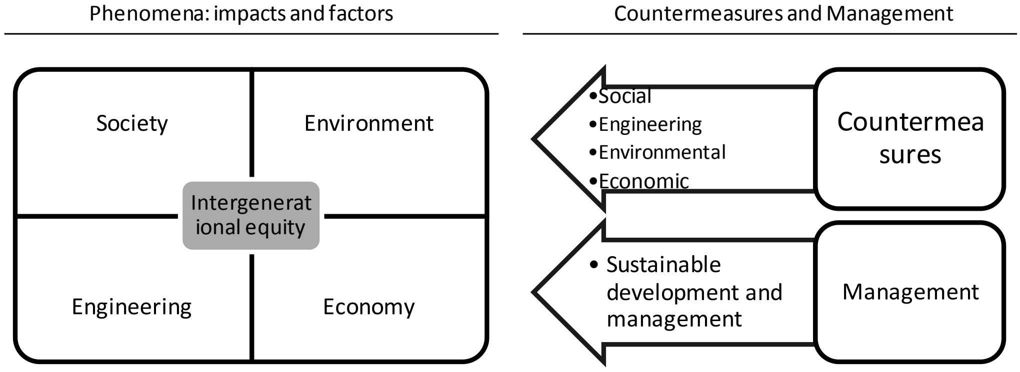


Figure 102 Framework of conclusion

10.2.2 RESEARCH METHODS

10.2.2.1 Literature review

The impact of population decline on sustainable infrastructure management is summarized based on the discussion in previous related chapters. Previous chapters can be categorized from both the managers' and users' sides, as shown in Table 74. The following discussion considers this difference.

In terms of countermeasures, a fair amount of relevant literature exists but only a limited amount of studies are referred to here as most of them were written by the author of this study as well as the most relevant literature introducing the case studies from Japanese magazine articles. The results of the literature review on case studies of countermeasures are mainly introduced in the discussion section in order to introduce the actual application of the concept model of countermeasures to the real world. Accordingly, the discussion is not comprehensive but focuses on key points relevant to achieving sustainable infrastructure development and management. Regarding further research tasks, some tasks have already been identified in my previous research, so references are made to them.

Table 74 Related to the chapter on the discussion of phenomena of the impacts of population decline on infrastructure management

Managers	Users
Chapter 4 (Interview) Chapter 5 (Binary logit regression analysis)	Chapter 6 (Choice experiment)

10.2.2.2 Spatial analysis

This section also introduces the case of spatial overlay analysis between population change in the future and network of gas distribution pipelines in order to illustrate the impacts of population decline on network infrastructure as well as to discuss potential countermeasures.

This type of special analysis is merely conducted because of difficulty in collecting infrastructure network data. This time, the Tosai Gas Inc. cooperated and provided the distribution gas pipeline network data for the author.

This analysis is conducted by three steps. First, the 500m by 500m resolute projection of population and the number of households was conducted using the National Census in 2010 and the assumed parameter for the official projection set by the National Institute of Population and Social Security Research (IPSS). The method of projection is normal cohort analysis. The change of household in the region was calculated by deduction of the number of households in 2010 and that in 2030.

The second step is to categorize every mesh by two dimension criteria. The first dimension criterion is the number of households in 2030. 20 households and 200 households are thresholds. The second dimension criterion is the household change. 10% decline and 10% increase are thresholds for this dimension. The combination of two dimensions can produce 9 cells and they are scored.

The third step is map drawing and overlaying the results of scoring cells and the gas distribution pipeline network. This is simple analysis, but can visualize which network will be affected by the population decline in 2030.

10.3 RESULTS

The research results from previous chapters are summarized here and compared with previous research results conducted by other researchers and a comparative discussion between chapters in this study is also carried out. Through this discussion, it is intended to clarify what the impacts of population decline on sustainable infrastructure development and management may be.

10.3.1 Comparison to the previous studies

The literature review in chapter six (Uemura and Mourato, forthcoming) introduced a discussion on the impacts and issues of population decline on infrastructure development and management in previous research. Here, the research results from this study will be compared with the results of previous research and the contribution of this study will be clarified and critical reviews of previous research will be also conducted. It is expected that these discussions will result in identifying arguable points and further research tasks for promoting sustainable infrastructure development and management in depopulating areas.

10.3.1.1 Population decline

As a result of this study, it has been found that population decline, infrastructure development and management are related to the types of infrastructure and the types of impacts involved. Also, it is difficult to say whether the impacts reported to have resulted from population decline in previous research may have been caused directly by population decline without fully considering the role of administrative reforms in those depopulating municipalities, based on the analysis of Japanese depopulating municipalities. Indeed those public administrative reforms were often conducted to cope with population decline, and with some awareness of how local government would take possible countermeasures, so we cannot instantly conclude that there is not necessarily any relationship between population decline and impacts and issues related to infrastructure development and management. For more discussion, case studies on individual municipalities and analyses of logical cause and effect chains using a structural equation model should be conducted.

10.3.1.2 Infrastructure types

In previous studies, the impacts of various types of infrastructure in depopulating areas were reported. In this series of studies, the impacts on all seven types of infrastructure located in depopulating areas that are likely to relate to population decline were reported on. The seven types of infrastructure were categorized into three types, namely point type, point-network type and network type, and the differences caused by those type differences were discussed. Consequently, the point-type infrastructure for public facilities is more easily affected by population decline than other types of infrastructure. In addition, the economic impact can be assessed for the point-network type infrastructure, which is often managed and operated using a user charge system, in contrast to the point type and network type infrastructures which are usually financed by tax or governments so can be protected from economic impacts.

10.3.1.3 Geographical variety

Geographical varieties such as the differences between urban and rural and plain lands and mountainous lands were pointed out as the factors of changes of impact occurrence in previous studies. In this study, these geographical varieties were also tested in the quantitative analysis. As a result, the results of geographical variety in previous research are confirmed here in the comprehensive quantitative analysis of various types of infrastructure and various types of impacts. Concrete, urban areas tend to suffer more from population decline than rural areas. This is because the parameter of ‘DID’, the proxy of the urban area, was shown in chapter eight to be statistically and positively significant for public facilities. In other words, the public facilities located in urban areas are easily affected by population decline. The results for road and water did not show such an analytical result, but it means that the difference between urban and rural is not significant for impact occurrence. As introduced in chapter four, urban areas in Japan have more infrastructure than rural areas. Both findings lead to the conclusion of highly likely impact occurrence in urban areas, once the same size of population decline per unit area will happen in both urban areas and rural areas.

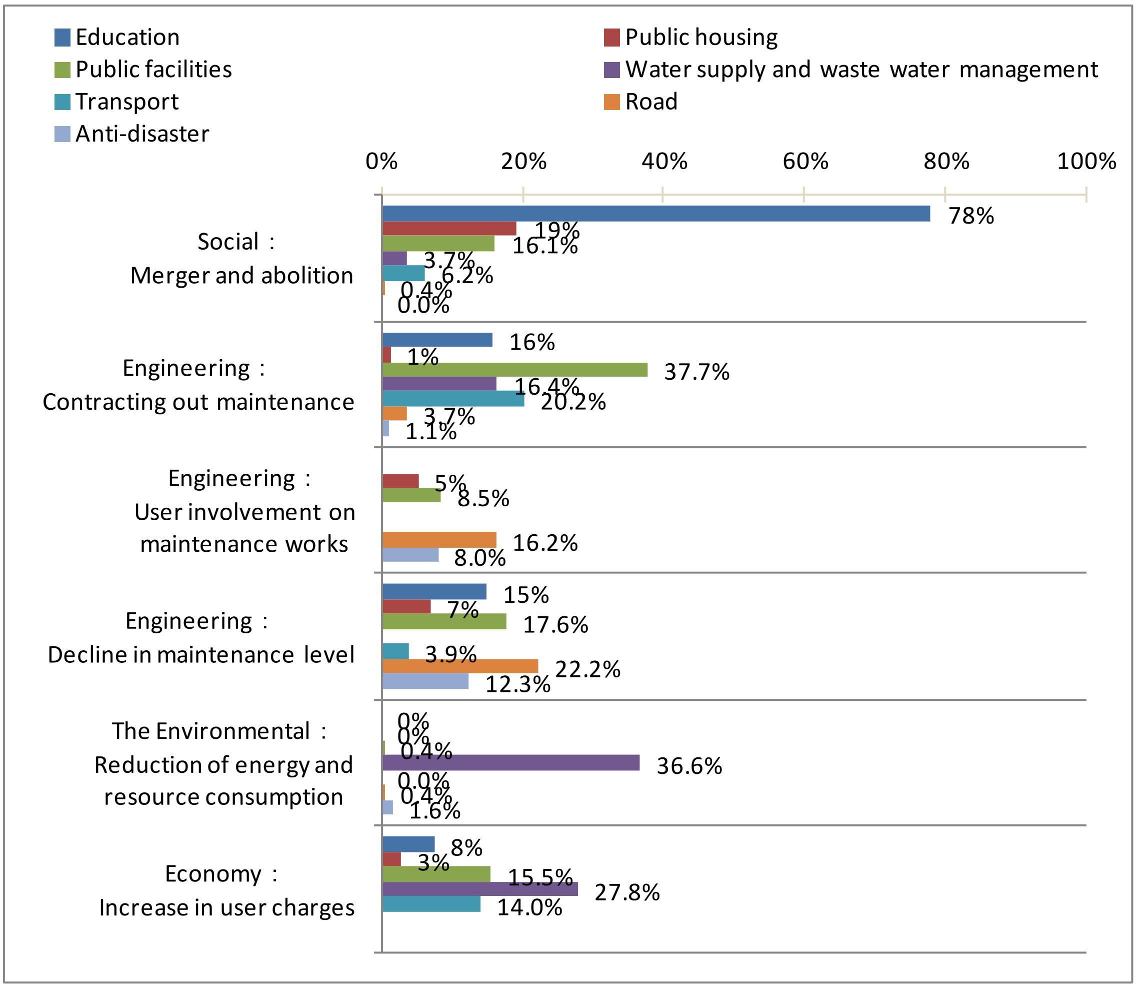
Of course, economic factors such as increasing charges on the usage of public facilities tend to be observed more in rural areas, or a decline in maintenance levels tends to occur in the municipalities in less habitable areas.

Hence, it cannot be said clearly that geographical factors are one of the significant causes of the impact occurrence of infrastructure management in depopulating regions. Actually, this is also not a fixed relationship, so that the relationship between each impact on infrastructures and geographical features should continue to be discussed carefully.

10.3.1.4 Impacts on infrastructure management

Previous research has pointed out many possibilities of impact occurrence using case studies and questionnaire surveys for limited areas. In contrast, this study conducted a survey of all depopulating municipalities and infrastructure users all over Japan. Therefore, more completeness was achieved compared to the previous research results.

According to these comprehensive study results (Figure 103), natural population decline originates in low fertility rates and education facilities are the first victims of negative demographic change. In Japan, more than 80% of depopulating municipalities experience merging and abolishing of education facilities while only around 20% of depopulating municipalities experience merging and abolishing of public housing and public facilities.



Source: Nomura Research Institute (2008)

Figure 103 Reported impacts of population decline on seven types of infrastructure

As population decline becomes more severe, those point-type infrastructures will suffer more from population decline, and merging and abolishing facilities will become common place in the future.

Engineering impacts and countermeasures for the decline in users and the deterioration of infrastructures are two sides of the same coin. The selected countermeasures, in other words, and the occurrence of the impacts, are different depending on the types of infrastructure.

On the other hand, the decline in resource usage was regarded as a positive environmental impact and attracted low levels of response from all infrastructure types apart from water and waste water management. This is because the purpose of water and waste water management infrastructure is to deliver plenty of water resources. Of course, an unconscious decline in resource usage cannot be grasped because of the constraints of survey methods, while a more detailed survey of quantitative case studies using particular accounting methods is required to confirm whether the resource usage is actually declining or not.

The study results suggest that it is hard to find any consistent situation of impact occurrence of population decline within each infrastructure. It can be considered that the cases discussed in the previous research introduced in the literature review chapter probably happened as a result of necessary conditions of population decline added by some sufficient condition. This sufficient condition is not yet clear. One thing that can be pointed out from the literature review, interviews to infrastructure managers and questionnaire surveys is that the impact has not become serious in case that mayors and government officers take precautional countermeasures. In short, the interpretation that the precautional corresponds to a wise monarch could prevent the severe impact occurrence. In other words, the many conditions will not necessarily and solely become a trigger of impact occurrence.

If this consideration is correct, for getting policy implication, it can be said that the future research should focus more on the reasons why cases with the same background conditions of impact occurrence don’t have any significant impact.

10.3.1.5 Summary

According to this series of studies, the impact of population decline on sustainable infrastructure development and management vary depending on the types of infrastructure, and are affected by geographical features. When these impacts are discussed, individual rather than comprehensive discussion is required. In other words, more detail and highly resolute spatial analysis on this topic is expected.

10.3.2 Differences between stakeholders

Previous studies did not use any clear framework like sustainability when they discussed the relationship between population decline and infrastructure development. Consequently, two unique factors in the balance between multiple aspects and intergenerational equity that characterize sustainability could not be discussed.

By focusing on these two unique points, making a comparison with research results from two opposite sides in the form of infrastructure managers (chapters seven and eight) and infrastructure users (chapter nine), issues about realizing the sustainable infrastructure development and management in Japan would be clarified.

10.3.2.1 Population decline

It may be expected that responses from infrastructure managers and users regarding the extent of population decline would ideally be different. The results were certainly different from the assumptions. It could be observed that the relationship between the causes of population decline and the impacts of population decline vary due to the types of infrastructure and impact, but only limited difference caused by the extent of population decline can be observed. However, an analysis of the responses between the four aspects and the timing of infrastructure development from infrastructure users suggests that there is no clear difference between the responses from respondents living in depopulating areas and non-depopulating areas.

This may also lead to shortening the gap between infrastructure service provisions with regard to the demands of infrastructure managers and infrastructure service demands by infrastructure users.

Infrastructure managers can cope with the impacts of population decline on infrastructure management by considering the causes and extent of population decline and other relevant factors, while infrastructure users can expect the same level of infrastructure service provision regardless of where they live. Infrastructure managers need to cope with this cognitive gap as well as with the physical impacts of population decline on sustainable infrastructure development and management.

10.3.2.2 Balance of aspects on infrastructure sustainability

In chapter five, the radar chart was used for checking the balance between the probabilities of impact occurrence on each of four aspects estimated from the response from infrastructure managers in order to discuss the balance between multiple aspects, as one of the unique features of sustainability. In chapter six, the other radar chart was constructed by using the coefficients on the four aspects from choice modelling.

As regards the latter, the absolute value of each aspect will change because of the units of the analyzed data set, so we can discuss not the absolute shape of the radar chart but the relative difference between infrastructure types that represent an evaluation by infrastructure users and will be probably discussed if the units of the choice sets are aligned. Indeed, two analyzed results cannot be simply compared because different indices are taken on each side of infrastructure managers and infrastructure users in this study, although it can be said that infrastructure managers tend to recognize the social impacts but infrastructure users tend to focus on the safety issues in terms of engineering aspects. This can be considered as one of the detailed gaps between infrastructure managers and infrastructure users.

The sustainability of the infrastructure development and management should be based on the weak sustainability and in principle, the balance between the economic aspect and the integrated other aspects is the condition of the sustainable situation. In order to assess this situation, it is required that the level of change of multiple aspects other than the economic aspect should be made into an integrated indicator using, for example, an analytic hierarchy process. This point needs more discussion in future studies.

10.3.2.3 Intergenerational decision making

Intergenerational equity is the final arguable point in the sustainability discussion, but could not be pointed out in previous studies. According to the results of this study, infrastructure users are not concerned whether there is any infrastructure development and management after their death. Even in case that they might have either descendants or property which should be inherited, they may be not able to conduct rational decision making when they are alive. This suggests that in general people cannot conduct rational decision making in the long term. This possibility rejects Barro's (Debt) Neutrality Theorem on public financing. Consequently, infrastructure development financed by public debt in the current generation will probably leave excessive financial burdens for future generations. The future generations who have not been born cannot stop the decisions being made by the current generation. Thus, intergenerational inequity may occur.

This situation is actually unavoidable, and we have to make decisions about infrastructure development and management with regard to adverse changes in the current or future generations in the context of this inequity. As a result, undemocratic processes will decide what infrastructure development and management will be executed and decision making by 'wise monarchs' such as engineers or policy makers will occur. In addition, the social system which can support a wise monarch's decision making will have to evolve as part of sustainable infrastructure development and management.

10.3.3 SUMMARY OF RESULTS

This study provides additional knowledge about the issues and impacts of population decline on infrastructure development and management differentiated by the extent of population decline, the variety of geographical features and types of infrastructure. Furthermore, this study has shown how to consider the issues and impacts of population decline on infrastructure development and management and what type of management should be expected from both infrastructure managers' perspectives and infrastructure users' perspectives.

As a result of phenomenological study, several further research tasks are abstracted. In the next section, the countermeasures for sustainable infrastructure development and management in depopulating areas and what should be expected in terms of the sustainable infrastructure development and management in the context of population decline will be discussed.

10.4 DISCUSSION

The possible countermeasures for sustainable infrastructure development and management in depopulating areas and the ideal form of sustainable infrastructure development and management in depopulating areas will be discussed.

10.4.1 COUNTERMEASURES

The basic idea of countermeasures for the impacts of population decline on infrastructure development and management is illustrated in Figure 104. The premise as well as the constraint of considering the countermeasures is for infrastructure managers to have to follow the given demographic change decided by the age and sex of the current population as well as the history of infrastructure development in the region. Accordingly, the process of coping with demand change on infrastructure is also deterministic, and comes to be path dependent.

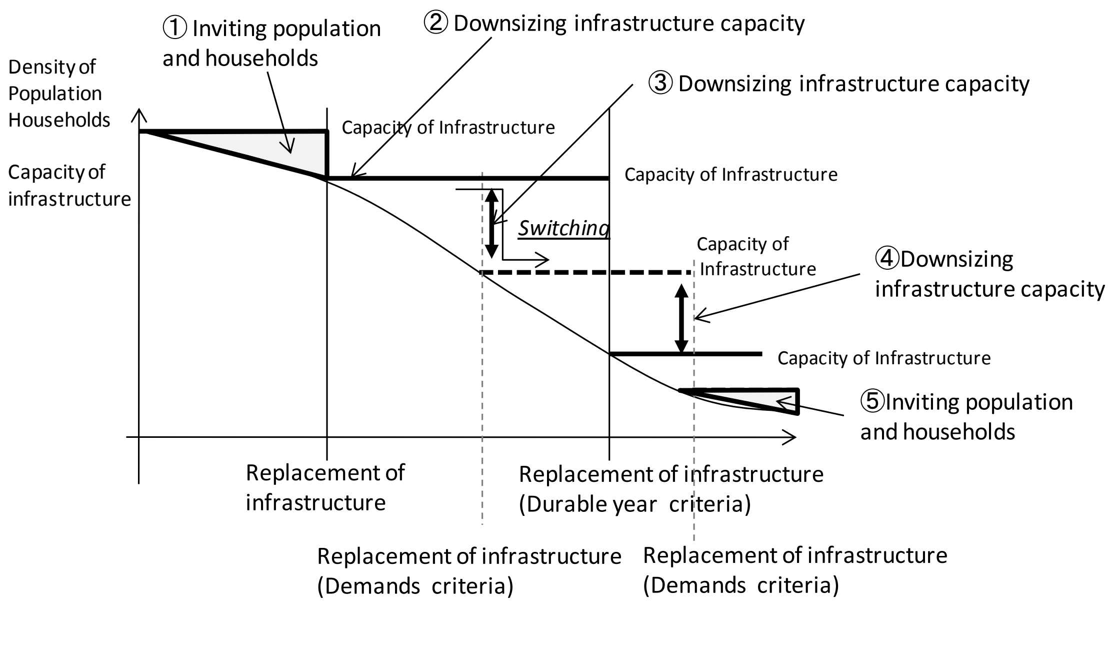


Figure 104 Demand and capacity change of infrastructures in the process of population decline

Of course, the path illustrated in Figure 104 is really a simplified case and it is merely observed in an actual situation. Therefore, assuming this simple path case, the countermeasures should be explored against reality. The aim of this section is on that point.

In previous studies, a partial demolition and decline of maintenance levels and outsourcing for cost reduction have been proposed as countermeasures. When discussing countermeasures, their repercussions need to be evaluated.

For example, partial demolition against the economic impacts will lead to a decline in the service levels of infrastructure service provision. Abolishing infrastructure service, without demolition and restoration, will contribute to solving economic issues but may cause environmental problems (such as the deterioration of the landscape) and social problems (deterioration of safety). In this way, we should bear in mind that one solution for one impact or issues will sometimes cause a reflected negative impact when developing countermeasures. To avoid these unexpected situations, cocktail treatment (a combination of multiple countermeasures) is required.

Before consolidating countermeasures, the following subsection introduces the countermeasures for each aspect of social, engineering, environmental and economic impact which was individually shown in the previous reports and studies by the author and a discussion of the repercussion of various impacts will be carried out. Note that most countermeasures are related to aspects of engineering, but are also considered as social and economic countermeasures. The following subsection will discuss how to manage those multiple possible countermeasures.

10.4.1.1 Social countermeasures

Social countermeasures can involve downsizing the capacity of infrastructure, so that the infrastructure remains located in the same place, while the amount of infrastructure service will be reduced to an appropriate level. With regard to merging and abolishing infrastructures, the infrastructure may be demolished physically or the integration of two or more infrastructures could be considered. These countermeasures are very common and are often observed in the cases of demolition of flats in eastern Germany.

Partial demolition can only adjust the supply of infrastructure capacity to the demands and will not result in a decline in the level of infrastructure service provision and it can also reduce the maintenance costs per user. Of course, some buildings and structures cannot be demolished because of the constraints of the engineering structure. Partial demolition is, therefore, not a panacea in all situations.

On the other hand, merging and abolishing the infrastructure will sometimes result in the service level going down. For example, the abolition of a library in a depopulating area will require users spending more time in another library or giving up using the library completely. To cope with this situation, Private Financial Initiatives (PFI) and Public Private Partnerships (PPP) can be introduced to purchase infrastructure services from the private sector[11]. The government of Japan, along with European countries, would also promote PPP and PFI.

When the infrastructure managers stop providing infrastructure services, they could sometimes not remove physical structures owing to the lack of finances. This situation leads to negative side effects like the deterioration of the landscape. In fact, in 2009 in Japan, the rate of leaving infrastructure after abolishing infrastructure services had reached up to 37.8% of public facilities (Table 75).

Table 75 Situation of post-closure infrastructure

	Total response a	No. of suspended infrastructures b	Rate of occurrence b/a (%)	No. of derelict infrastructures owing to lack of budget c	Rate of leaving c/a (%)
Education	464	362	78.0	93	25.7
Public housing	457	88	19.3	21	23.9
Public facilities	459	74	16.1	28	37.8
Water and waste water management	464	17	3.7	2	11.8
Transport	129	8	6.2	2	25.0
Road	464	2	0.4	0	0.0
Anti-disaster	187	0	0.0	0	-

Source: Nomura Research Institute (2009)

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11 http://www8.cao.go.jp/pfi/e/home.html

In particular, with regard to the education facilities and public facilities which often remained when structures were not demolished, residents were often concerned with the deterioration of landscapes. Once strangers began to live in those vacant facilities, residents showed their intention to move out of the area (Matuoka and Uemura, 2009). Accordingly, when we consider merging and abolishing infrastructures, it can be said that we should develop countermeasures including demolishing vacant facilities and unused structures as well as trying to recover natural vistas.

10.4.1.2 Engineering countermeasures

Since 2013, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has introduced some technical policy to enhancing infrastructure development and management, in particular, in local government. The MLIT has introduced the comprehensive and cross-sector actions for infrastructure maintenance and replacement as follows (Table 76) in order for people to continue to use existing infrastructure at ease (Ministry of Land, Infrastructure, Transport and Tourism, 2014).

With regard to long term planning, asset management of infrastructures for prolonging their physical durable years and declining maintenance levels is decided by the balance between risks and costs known as engineering countermeasures. These countermeasures have already been introduced to many infrastructure developments, but do not in themselves represent a panacea. For example, it is inappropriate in terms of social aspects that an infrastructure with too much capacity could be sustained until the coming year, even if it could be considered as being valid from an engineering perspective. In addition, postponing replacement timing through asset management can limit the opportunities for transfer of technologies, even when the decline in the demand for infrastructure will reduce the opportunities to construct infrastructure, indicating decline in the opportunities to transfer the technology to future engineers so that the same technologies could not be used so often. This means that engineering countermeasures could create other issues in the area of engineering. This is the difficult point when we develop countermeasures for the issues and problems of population decline for sustainable infrastructure development and management.

Table 76 Comprehensive and cross-sector actions (Cabinet Decision, 21st March, 2013)

Menu	Actions
Comprehensive inspection and repair	Concentrated inspection to avoid serious damage on users was already done in 2013, and repairs are promoted in 2014.
Development and review of standards and manuals	Based on previous experience and results of inspection, the inspection items and frequency in the inspection standard and manual was developed or reviewed in 2013, and new standards and manual are implemented in 2014.
Data base development on maintenance and replacement	The data base reflecting the current conditions of infrastructures are being developed. The prototype of information platform was developed in 2013. The function of the platform is now being developed in 2014.
New technology development and implementation	Non-destructive inspection technology and robots for maintenance work are being developed. In terms of robots and monitoring technology, the special committees were launched and field tests of some technology are being conducted in 2014.
Support to local governments	Grant of anti-disaster and safety is the financial aid from central to local government. In addition, support consultation service on deterioration of infrastructures is established in regional development bureaus in 2013.
Securing engineers for maintenance works	Tender process and contract management method have been improved to secure human resource development of infrastructure engineers because usual general competitive tender system has introduced over-competition and has resulted in exhaustion of engineers and retirement too much.
Development of laws and regulations for national level management system establishment	MLIT launched infrastructure ageing countermeasure promotion office in March 2013 to promote the uniform policy. In addition, the necessary regulatory reforms on the road act, the river act and the port act to introduce common inspection standard.
Promotion of Long Life Plan of infrastructure	MLIT has encouraged municipalities to develop long life plan of infrastructures, in particular, on coastal protection, dams, anti-land slide facilities as well as river, park and road. Also, the MLIT is considering to develop the new national certification on maintenance and inspection as well as to launch new professional association of engineers. Moreover, the new cross-border organization over multiple municipalities is also discussed for the better maintenance of infrastructure

Source: Ministry of Land, Infrastructure, Transport and Tourism (2014a).

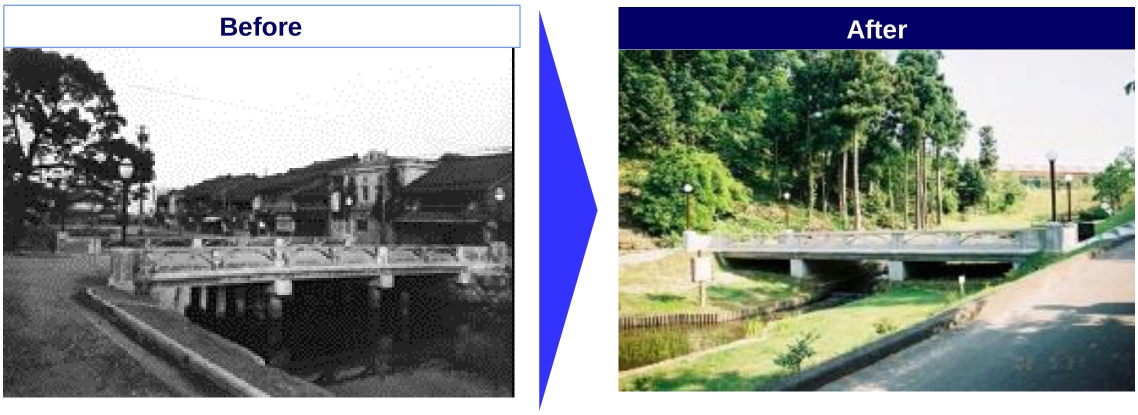
The decline in the level of maintenance also has another type of trade-off. It is known that a decline in the level of maintenance sometimes increases the risk of accidents. This can be appropriate from an economic perspective, but not in terms of social aspects.

In this way, these well known engineering countermeasures may have limitations as solutions. Therefore, the other countermeasures should be discussed here. It also enables the enlargement of potential choices of engineering countermeasures. The other solutions can be divided into countermeasures on the structure of infrastructure and countermeasures on technology (or skill) transfer and securing the number of engineers.

Firstly, it is about countermeasures of infrastructure structure. The issue of population decline with regard to infrastructure is a decline in the demand for infrastructure socially and economically for a shorter period than the period of its own physical durable years. Naturally, the infrastructure will be made of iron and concrete, which are hard materials. This means that infrastructure cannot be adjusted to the demands for change very flexibly. This inflexibility requires the users to take on a higher financial burden than previously. In short, the mechanism of impact occurrence means that the technical features of infrastructure cause an economic impact. In order to manipulate this mechanism, the nature of the infrastructure should be changed to become more flexible with low costs. The countermeasure proposed for this point is modular, and the standardization of structure demands reusing precast concrete parts (Uemura, 2012a).

The idea of the modular is not to construct one big and long-term durable structure, but to build up module-architecture using long-durable standardized parts. For example, instead of developing one large diameter pipe, two middle size diameter pipes will be developed and once the demanded change occurs, one is closed or demolished, but only the other will be used. Thus, the infrastructure managers can easily adjust their infrastructure to suit future demands. This technology has been already introduced for skyscrapers, flyovers, and data centre construction.

The modular method will enable us to reuse unnecessary parts in the previous infrastructure in parts of the new infrastructure. The standardization of parts is sometimes required to make reusing such parts possible, but existing cases are not required for such a standardized structure. In Japan, there are two bridge cases. One is the case of the first pre-stressed concrete bridge, 'Cho-sei-bashi', in Japan. It was constructed in 1951 in the city of Nanao, and was removed and moved to Kibou-no-oka Park in the city of Nanao for use as a pedestrian bridge in 2001.



Source: Uemura (2012a) and
http://c-pc8.civil.musashi-tech.ac.jp/RC/class/rceng/rceng_pdf/h15/h15_10.pdf (available on 9th August, 2014)
http://www.psmic.co.jp/kaisya/cyousei_p.html (available on 9th August, 2014)

Figure 105 Reuse case of pre-stressed concrete bridge in Kanazawa

The second case is the Pratt truss bridge made of iron, called ‘Kasmi Bashi’, over the Shin Yamashita Canal in the city of Yokohama. The original bridge was, firstly, constructed for Sumida River Bridge on Joban Line in 1896. The bridge moved to the Old Egasaki overpass due to load increase of locomotives in 1929. This bridge was removed again in 2009 because of too narrow width and deterioration. Before removal of this bridge, this bridge was often known as ‘100 Bridge in Kanagawa prefecture’, ‘100 Iron Bridge’ and ‘Modern civil engineering heritage of Japan’, so that the bridge moved again as Kasumi Bridge (Ministry of Land, Infrastructure, Transport and Tourism, 2014).

Original source: The City of Yokohama
Source: Ministry of Land, Infrastructure, Transport and Tourism (2014a)
http://www.mlit.go.jp/hakusyo/mlit/h25/hakusho/h26/index.html (available on 8th August, 2014)

Figure 106 Reuse case of Iron Bridge in Yokohama

Of course, the various types of standard precast concrete have been already introduced, but these do not cover all situations. Actually, these two cases are special cases because of their heritage value.

For promoting this countermeasure, however, we should also make more efforts to develop standards of modular or pre-cast concrete parts for all types of infrastructures.

The second point is about technology (or skill) transfer or securing the number of engineers.

It is easily understood that not only the numbers of users of the infrastructure, but also the engineers of infrastructure management will decline in a depopulating society. In Japan, reduction of public investment for infrastructure development and management by fiscal constraint has resulted in a faster decline in the number of engineers for infrastructure development and management than the speed of population decline now or that can be allowed in the future (Uemura, 2012b).

As regards this issue, we could find the interesting case from Ise shrine. The Ise shrine has been replacing its own building every 20 years using unique architectural technology called the Yuiitsu Shinmei Dukuri for 1300 years. It is natural that sustainable infrastructure development and management require sustainable technology transfers. When we discuss this point, we should, however, remind ourselves that the life expectancy of engineers is normally less than the physical durable years of the infrastructure. In the case of the Ise shrine, engineers can experience the rebuilding of the unique architecture three times from every twenty years' rebuilding and may have succeeded in gaining unique skills from ascendant engineers to descendant engineers (Uemura, 2012c).

It is certainly true that transferring technology may need the stable employment of engineers as well as a certain number of generally skilled workers for adjusting the labour force, whose skills are common to other areas of construction work in order to realize sustainable infrastructure development.

Of course, these stable employments will raise the labour costs and capital investment and the packaged countermeasures of any cost reduction are also necessary. In the case of the Ise shrine, the reuse of parts of previous architecture and limited numbers of dedicated engineers constrain unexpected cost increases. Asset management can organize technology transfers, and can also contribute to cost reduction, so that efforts can be made over the years to use the opportunities for technology transfer through standardization of technologies and finding potential ways of standardizing them to the opportunities of infrastructure development.

With regard to securing engineers, the private company also makes their efforts. For example, Sekisui Chemical Co. Ltd. opened its engineers' training school in the factory and tries to increase the number of its engineers with the national certification of the Civil Engineering Works Execution Managing Engineer from 100 in 2014 to 300 in 2016 (Anonymous, 2014e).

When engineers consider the sustainable development and management of infrastructure, they tend to focus on prolonging the physically durable aspects of the infrastructure, but the most important point is to provide the function of infrastructure in accordance with the users' demands because infrastructure is only a tool for people to enjoy their safe and comfortable lives. Therefore, engineers also have to try to find alternative ways to provide similar types of infrastructure service substitutable for the original infrastructure. Otherwise, assuming the destruction of infrastructure someday, they should try to introduce the partial downsized or down-graded infrastructure whose services are most easily recovered. Furthermore, it may also be important that they should not only consider the sustainability of the whole structure, but also of parts of the structure premising replacing deteriorated parts to sustain the whole function with the minimum cost.

The above mentioned choices are expected by professional engineers, but there are limited numbers of professional engineers as government officers in depopulating small municipalities. Therefore, supporting systems to share the technical engineering knowledge with infrastructure managers working at the frontier of infrastructure development and management in the context of population decline should be prepared. In Japan, as introduced in chapter four, the central government has already introduced some policies. For example, the MIC has requested to develop the comprehensive management plan of public facilities to all municipalities. The plan is expected to be a 10-year long-term plan, to establish all department inclusive regimes for copying with the issues of public facilities management, to develop information management and sharing system, to develop basic management policy based on the analysis of the actual situation, and to publish how to disclose and update information.

The financial source for these activities are a special grant programme (50% subsidy) for three years from 2014 and a special permitted local bond (75% allocation and maximum 30 billion JPY in all Japan) for the demolition of public facilities based on the plan (Ministry of Internal Affairs and Telecommunication, 2014).

As introduced in the beginning of this subsection, the MLIT has also introduced a couple of policies to provide the opportunity to consider the infrastructure situation from a technical perspective and try to promote the technical knowledge transfer through this opportunity.

In this way, it can be considered as important to develop technical solutions, supporting systems to transfer the technical knowledge as well as the planning scheme as countermeasures.

10.4.1.3 Environmental countermeasures

The environmental issues include potential pollution, landscape deterioration and increases in resource consumption. According to this series of studies, pollution was been reported in the process of depopulation in contrast to the process of population or economic growth. In eastern Germany, the possibility of the potential occurrence of odour in the water and waste water management was pointed out, but there has been no reference to it in Japan. Accordingly, pollution may not occur as a result of population decline in any way. Similarly, landscape deterioration is not usually a serious problem as long as the infrastructure can continue to be used.

The problem of landscape deterioration can be caused after infrastructure service provision has ceased and derelict infrastructures are no longer looked after (as described earlier). This matter is the other side of the coin of the economic problems. If infrastructure managers of depopulating municipalities face serious and strong financial constraints, subsidies for the demolition of the vacant infrastructure from the central government may be expected. Statumbau Ost, which is the German programme, is one typical subsidy scheme for demolishing vacant facilities and reconstructing and reorganizing deteriorated urban areas[12].

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12 http://www.stadtumbauinfo.de/

On the other hand, reducing natural resources can have a positive impact even in a depopulating society. This is because the decline in the number of users automatically reduces resource consumption. Reusing and recycling are representative ways of reducing virgin materials.

Reusing has already been pointed out in the subsection on engineering countermeasures, but modularization and standardization assume reuse since the design phase will, if precast concrete parts are introduced, have become feasible in spite of demolitions, merging and abolishing.

As for buildings and structures that cannot be reused, attempts to reuse scrap iron from demolition and regenerate the crushed concrete pieces as aggregates of concrete have already been carried out. The Construction Material Recycling Act was introduced In Japan in 2000 and enacted in 2002. The regenerated materials derived from this have already been used as materials for the construction of road beds and concrete blocks and steel rods and wide-flange beam steel, known as H-type steel. These efforts are expected to contribute significantly to transforming usual infrastructure developments into sustainable elements of infrastructure.

It is true that the cost of using recycled materials is higher than using materials from virgin resources. However, the required capacity of the infrastructure in depopulating society will have to be shrunk anyway even if the new infrastructure is required to follow the new types of demands. As part of this process, the demand for construction materials will also decrease and they will be procured on the basis of physical quantity from the area where the development project locates. This procurement will enable a reduction of logistical costs for transporting the construction materials, and will lead to a decrease in the price of recycled materials for the construction. Thus, efforts to save virgin materials to reduce the total costs of construction in the future are highly expected to bring other possibilities of introducing a recycling-oriented society in depopulating regions from resource consumption and sustainable infrastructure development perspectives.

10.4.1.4 Economic countermeasures

Infrastructure development and management are often conducted by types of governments in many countries. However, either in developed countries or developing countries, a Private Financial Initiative (PFI), which uses private funds firstly to construct an infrastructure, can be initiated. In such a case the government may reimburse all the costs including maintenance and operational costs on an annual payment basis. Such measures are often introduced to promote infrastructure developments. In addition, Public Private Partnerships (PPPs), a much wider concept than PFI, and which invites the private sector into infrastructure development and management in many ways, has become very common in the world of infrastructure development. These methods have already been covered in many previous studies, so this study can only focus on and discuss three types of potential economic countermeasures: namely, the inter-governmental tax allocation system, financial cooperation with a private sector including PFI, and nonfinancial cooperation with the private sector.

On the other hand, the privatization of infrastructure operation and management, which can be often observed in the water and waste water management sector, airport management, railway services and so on in the United Kingdom, is not applicable here. This is because the premise of privatization is generally to make a profit from infrastructure management; apart from a minor example such as Welsh Water, which is a non-profit private water management company in Wales. In addition, most parts of the infrastructure which charge fees and fares for users in depopulating regions operated by local governments cannot be covered by the revenue for user charges because of the small number of users compared to the minimum capacities of infrastructure. In other words, infrastructures in depopulating areas are basically impossible to manage using the private sector alone. The infrastructure in depopulating regions can be, of course, managed by the private sector if the government will carve out a profitable portion, but government expenditure will then need to increase to support the remaining portion of the infrastructure because cross-subsidization stops. Indeed, the efficiency of infrastructure management will be improved tremendously, and the total social benefit will be improved as well, if the government is left to improve the management efficiency of the infrastructure. Hence, this study can only focus on the countermeasures and on privatization.

The first possible financial countermeasure is to use the inter-governmental local tax allocation system from the central government to help local infrastructure managers in local governments. As described in chapter four, Japan has a local tax reallocation system which can focus usefully on its infrastructure. This may help the local infrastructure managers in local governments to conduct minimum infrastructure management. If the amount of vacant facilities and their demolition costs are also covered in this system, the local infrastructure managers will be able to avoid the negative environmental impacts of derelict infrastructure. The government of Japan has already introduced a new policy, introduced as 'Syakai Shihon Sougou Kouhukin' (Infrastructure comprehensive tax transfer policy) in chapter four and has introduced asset management for bridges, in order to reallocate the financial resources from central government to local infrastructure managers. Modular and reusable parts should be also included in the conditions of this tax reallocation policy, so that an incentive for the expected infrastructure management in depopulating society will be provided for the infrastructure managers.

Also, the Ministry of Internal Affairs and Telecommunication has allowed using local bonds as much as 30 billion JPY per annum since 2014 as described before. The ministry estimates that the municipalities are enabled to demolish a maximum of 1000 facilities altogether in Japan. Also, the special treatment on local bond issues for the demolition of the facilities has been expanded only from drinking water supply to all public corporation activities including transport, medical services, as well as waste water management and so on. The total budget is as much as 12 billion JPY (Ministry of Internal Affairs and Telecommunication, 2013).

This is actually a big policy change because this local bond policy is against the public debt principle in Japan so far. The local bond for demolition will not produce anything to be utilized in the future. Nevertheless, the MIC and MoF could agree with introduction of this bond because this local bond enables the reduction of future maintenance costs in the middle and long term, to levelling replacement costs, and to improve and equalize the financial burden between current and future generations. The demolished infrastructure was typically constructed in the High Economic Growth Era, and the current generation could enjoy the benefit from the infrastructure service, but the future generation will not. The demolition in this generation will be justified from the perspective of intergenerational equity (Interview to MIC). In this way, the Japanese ministries have already introduced the policy for sustainable infrastructure management even in a depopulating society.

Secondly, the PFI involves highly expected solutions in reverse proportion to the budgetary constraints of the government. The possible countermeasure is using the land trust scheme in Japan. The Resona bank, which is a commercial bank in Japan, has recently introduced the new scheme to replace and downsize the deteriorated infrastructure. The bank focuses on the surplus land of deteriorated infrastructure and facilities. The demand for infrastructure service of course, declines, so space for facilities and equipment are already not needed as much as place before. The replaced infrastructure will be designed as more compact and enable production of surplus land to sell out to private sectors. The earnings from the sale to invest in replaced infrastructure and the municipality can earn a surplus of money above the investment for replaced infrastructure (Anonymous, 2014b). However, it has been reported that this may be difficult to introduce in depopulating areas (Uemura et al., 2010). In fact, private companies expect profitable projects in urban areas, but the local governments in rural and depopulating areas may carve out their unprofitable infrastructure as PFI projects or wholly contracted out projects. Local governments in rural and depopulating areas are typically small and there are often not enough officers in charge of infrastructure management. PFI requires infrastructure managers to prepare many legal documents and to have professional knowledge not only of engineering but also of financing and accounting. These practical differences prevent PFI from being promoted.

The third potential countermeasure is to utilize non-monetary resources in the private sector. The idea of non-monetary infrastructure development came from the Japanese ancient tax system in the seventh century. The tax system consisted of three different items as shown in Table 77.

This would involve the labour force and materials being directly invested in infrastructure management (Matsuoka, 2011). In particular, the cases of ‘Yo’, as residents’ involvement type of infrastructure development can be found in Japan as well as Germany. The typical objective areas are small scale infrastructure, namely, narrow roads, small rivers, drainage, and small buildings. In all cases, residents provide their workforce for infrastructure development and maintenance due to the lack of financial source in local governments.

Table 77 Modern version of 'So', 'Yo' and 'Cho' for infrastructure development and management in depopulating society

Concepts	Contents	Cases
So: Credit enhancement (previously, tax revenue by harvests)	Governments give assurance for private financing in order to develop infrastructure which result in reducing public financing	Nishi Sugamo Souzou sya in Toshima ward http://sozosha.anj.or.jp/
Yo: burden of labour force (previously, poll tax)	Instead of paying a user charge, users provide their labour force to develop or maintain infrastructure.	Michi naoshi Jigyo, in Sakae Mura, Nagano.
Cho: (previously, tax revenue by cloth)	Instead of paying a user charge, users provide materials to develop or maintain the infrastructure	Donation of a historic building as a museum as an alternative to constructing a new building

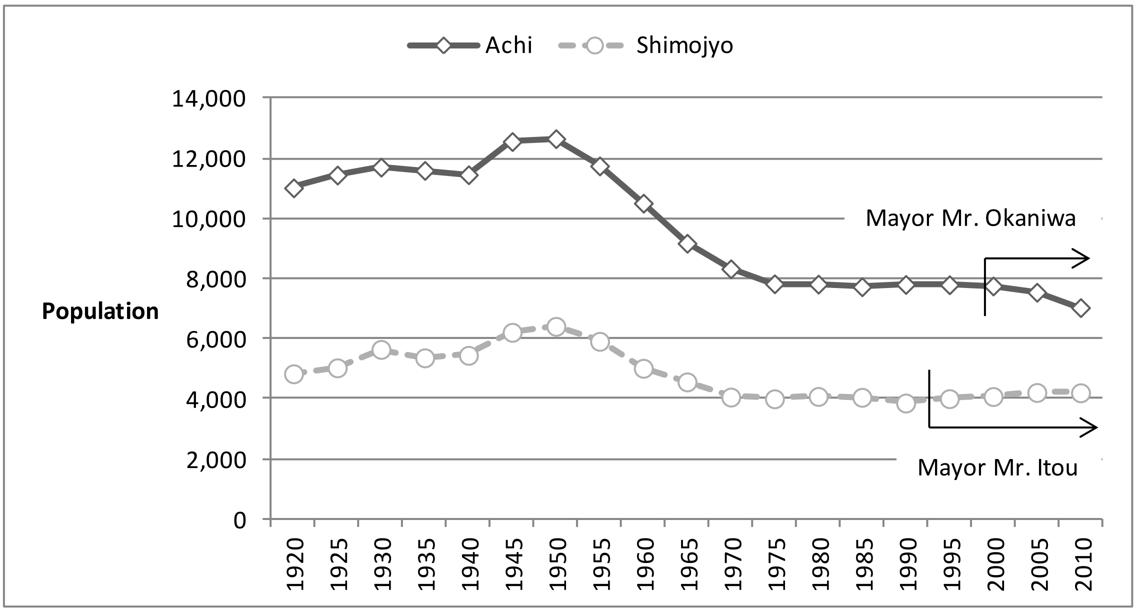
Source: Made from Matsuoka (2011)

Table 78 Cases of residents involved in infrastructure development and management

Category	Country	Municipality	Sector
Yo (Residential labour force provision)	Japan	The village of Achi	Road, River
		The village of Simojyo	Road, irrigation and drainage
		The city of Yanai	Road
		The city of Saga	River, canal and irrigation
		The city of Youbari	Hutte (Public building)
	Germany	Altena	Road
		Leipzig	Vacant house management
Cho (Material provision)	Japan	The city of Kawachi Nagano	Road

The following cases introduce the practical application of non-monetary infrastructure development and management activities so far.

The village of Achi in the prefecture of Nagano had a population of 7036 in 2010. Mr. Kazuo Okaniwa, who became the mayor in 1998 and was an ex-village government officer, promoted the village development by residents (Shinohara, 2006). The village had succeeded in inviting factories, but its production amount had been declining. The bond issuance balance has increased because of too much public work on road and waste water management facilities in accordance with the resort facility development of the spa of Hirgami, and the grant-in-aid from local allocation tax had declined, and then the situation changed making the village's financial situation worse. On the other hand, residents had depended on the easy works like garbage cleaning in irrigation system and snow-plough, which were usually managed by residential associations, or the village government. Against this situation, the mayor Okaniwa asked the six-village district to remake the residential association and then, all six residential associations were revitalized in one and half years. Next, the mayor promoted the development of each district plan by the residents since May 2002, and finally, all district development plans were completed in December 2013. For example, the district development plan in Komaba included the idea of the development of the dry river bed of the river Achi, so that residents themselves worked weed cutting, flower peach planting and digging the derelict land next to the dry river bed to make a small river. Finally, these areas will become a park. The theme of the fifth comprehensive plan for 10 years since 2008 is 'village development to enhance the quality of life of every village resident'. The word 'development' was later dropped from the theme (Shinohara, 2006). It may be a big choice whether a depopulating region will pursue the regional growth again or give up growth but pursue smart shrinkage (Richardson and Nam, 2014). The village of Achi has taken the latter choice.



Source: National Census of Japan (each year).

Figure 107 Population trend in the village of Achi and Shimojyo

The village of Shimojyo in the prefecture of Nagao had 4,200 people in 2010, and is a typical mountain village, but interestingly, the population is increasing again. This is because Mr Kihei Ito, who has been a mayor since 1992, introduced his unique policy to develop low-rent public housing for the young and to be free of medical bills for children less than 12 years old in order to promote young families to settle in the village, while he has entrusted residents to conduct small scale infrastructure development and management in order to cut off and save the budget on construction works (Anonymous, 2009).

The policy which entrusts residents to conduct small scale civil engineering work in the village is called 'Kensetsu Shizai Sikyu Jigyo [construction material grant programme]' and was introduced on 1st April 1995 (Table 79).

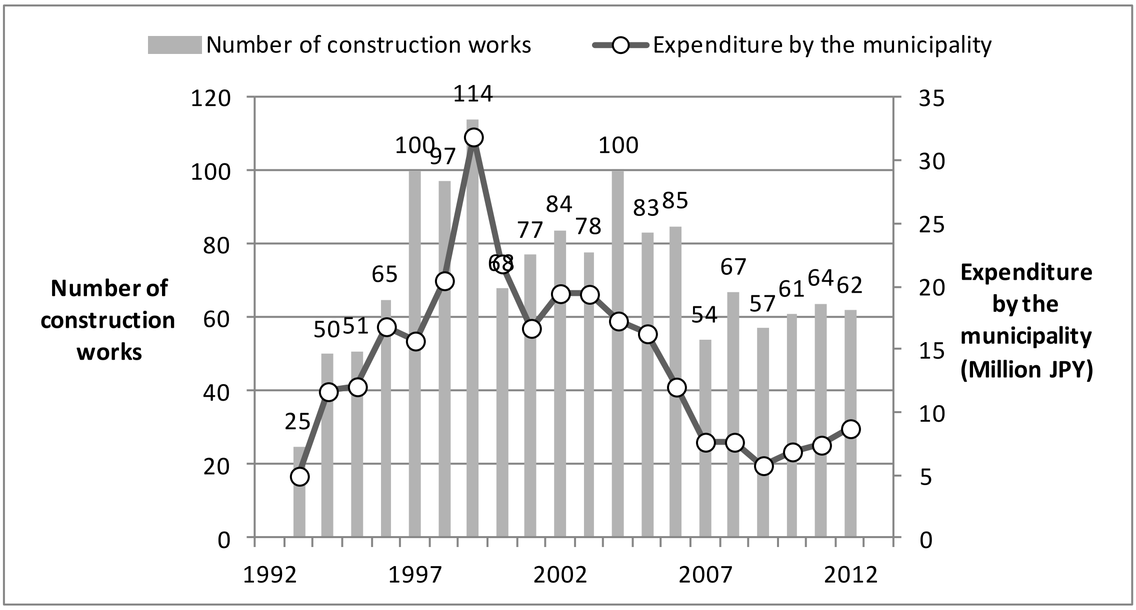
The village government provides the construction materials like concrete and crushed stone and pays the insurance cost for accidents, as much as 300 thousand JPY on behalf of the village people. There are civil engineers and technicians in the residents' association, and they take the initiative on necessary surveying and drawing for the construction work as well as guiding other village people. Initially, the village people resisted this policy, but now they accept it. The construction work size by residents is too small to be conducted by construction companies, and doesn't infringe the market for private construction companies. The local private construction companies, therefore, cooperate with this policy programme as they rent their construction heavy equipment at a reasonable price level.

Table 79 Outline of construction material grant programme in the village of Shimojyo (1st April 1995)

Items	Contents
Aim	This policy aims to develop living environment for residents and promote comfortable village life. For such purposes, the village provides construction material to the construction work conducted by residents themselves. This policy is expected to encourage the good solidarity among village people and to improve the living environment. Finally it aims to achieve better village development.
Objective of construction works	・ Road development (assumed materials are pavement, gravel, gutter laying, cross engineering, lid of the gutter, grating and so on, and expected more than three beneficial residents) ・ Agricultural road development (the same condition above) ・ Irrigation development (assumed burials are maintenance of soil gutter, repair of leaking, water-in-take facility development and so on , and expected more than three beneficial residents) ・ Other necessary construction work decided by the mayor
Application	The applicant is the president of the residents' association or the president of the irrigation association, and construction seekers confirm the needs of the work and ask applicants to apply for the village. Applicants offer to the village mayor on behalf of residents when applicants can agree with the needs of residents.
Construction permit	Once mayor can also agree with the needs, the mayor notices the acceptance and provides the construction materials as soon as possible. In case the mayor judges the inappropriateness, the mayor also has to notice it with the reason.
Construction work	The safety of construction work should be secured under the supervision of construction representative.
Completion report	Construction representative should report with given format and attaching related documents like material invoices right after the completion of construction work to the mayor as completion report.
Heavy construction machinery use	In case that the construction work needs to use the heavy equipment, the applicant notice the necessity to the village government officers, and ask the officers to give a permission to use it, and then rent it. The rent fee of it is also covered by the village following the decided rule.
Completion inspection	Mayor has to accept the completion report, and has to conduct the completion inspection as soon as possible.
Others	Other necessary conditions are decided by the mayor

Source: https://www.vill-shimojo.jp/01gyousei/05sumai/02kensetsu/2009-0405-2250-9.html (Japanese) (available on 6th August, 2014)

The results are remarkable (Figure 108). More than 50 construction works have been constantly conducted by the residents themselves since 1994. As of 2007, the village enabled a saving of 0.7 billion JPY as an outcome, namely, the village has spent only 0.2 billion JPY instead of 0.9 billion JPY estimated using the traditional way.



Source: https://www.vill-shimojo.jp/01gyousei/05sumai/02kensetsu/2009-0405-2257-9.html (available on 6th August, 2014)

Figure 108 Results of construction material grant programme in Shimojyo in Japan

In the city of Yanai in the prefecture of Yamaguchi, there are many roads with around 2m width. It is difficult for emergency vehicles like fire trucks and ambulances to drive on it. The city of Yanai introduced the policy of ‘Furusato no Michidukuci’ [Hometown road development], which expands the narrow road to a 4m wide road by the cooperation of residents, and 25 roads and a total of 2,285km of road were constructed by residents’ hands between 1994 and 2004 (Table 80). According to the policy, the city provides a maximum one million JPY to the residents’ association for purchasing construction materials and rental fees. The residents’ association makes consensus among residents and the city principally takes up the project in case the residents can provide their labour force and land for road expansion. The city conducts the survey and drawing for the construction work.

Table 80 Outline of 'Hometown road' development programme in the village of Achi

Items	Contents
Aim	The city would support the residents as community roads should be enhanced by residents by themselves and they can drive comfortably
Objective	· Expanded road will be with more than 4 m width, in principal, about city roads. · The other road but national road, prefectural road and agricultural road enabling to provide the road areas for public use and vehicle can pass
Application	Applicants submit the application form of hometown road development programme to the mayor. The applicant satisfies with the following two conditions. · The consent on land can be achieved · Residents can provide their own work force
Support	The mayor can grant material costs and rental cost of heavy equipment within the budget and maximum one million JPY after the reviews of application and in case it is judged as appropriate. The upper limit of support grant can be increased in the special case that the mayor can agree. The execution can be supported by construction companies and civil engineers financed by the city. In addition, design of construction should be done by the city department

Source: http://www.city-yanai.jp/soshiki/11/furusato.html (available on 6th August, 2014)

This policy saves time to purchase the land for road expansion. Normally, the city of Yanai has to spend a couple of years for purchasing land. In addition, the construction cost has become one tenth of the project cost compared with the similar construction project conducted by a construction company. Furthermore, this policy encourages residents to admire their road by residents, and residents also come to conduct repairs of road shoulder breaks by themselves (Shinohara, 2006).

In the case of the city of Saga, the city asks residents to clean the small rivers and water way of more than 2000km length in the city. The city lends rubber boots and scoops as well as transporting garbage and mud from the river and water way to waste management facilities. In 2004, a total of 66,153 citizens, equal to about one third of the total population of the city of Saga, joined in this activity and a total of about 2,600 tons of mud was taken off from the river and water way. The city could save about 30 million JPY for the civil work, and as a result, the water quality was improved, children could enjoy playing in the water way, and firefly can fly.

In the Yubari, citizens voluntarily reconstructed Yubaridake hutte previously owned by the city of Youbari, which has bankrupted. Yubaridake hutte is the base for patrolling rare species plants and wooden road development for climbing. Also it is an emergency shelter in Mt Yubari.

In 2008, the civic group was entrusted by the city of Yubari. They solicited donations from all over Japan (finally they collected 7 million JPY) and utilized the reused wood from a demolished primary school. Also, a total of 1700 members of the civic group and citizens spent two years voluntarily engaged in rebuilding work every weekend, and then finally the log-house-style building could be reconstructed by hand (Hatori, 2014).

Similar cases are reported in Germany. Alterna is one of the most famous cases. It is located in the periphery of theRuhrgebiet, which is an industrial region. Because of the decline of metalworking industry, the number of people in employment has declined from 9000 in 1970s to 5000 in 2012. The population also declined from 32,000 to 18,000 over 20 years. This is annually a 1.5%-3.0% decline. This shrinkage led to the closure of a sports centre, libraries, nurseries, and primary schools. Altena, however, has gotten the support of a charitable foundation, and developed a two-year revival spending plan. Finally, the participants of this discussion developed the plan of pursuing not economic growth but improvement of quality of life. In this process, the citizens were involved. For example, road improvement next to the river was attempted. The municipality procured the construction material, and closed the road on Friday and Saturday. The construction works were conducted with the motto of ‘get their hands dirty’ by residents, and repaved the road. It is considered that this process encourages the residents’ autonomy in Altena. Recently, the financing for developing a co-owned shop for providing the neighbourhood service has also been executed (Schlappa and Neill, 2013).

Also, in Leipzig, ‘Waechterhaus (guardian house)’ has started since 2004. This is because vacant houses were increasing because of the lack of investment. For this situation, architects, planners and residents could have developed new flexible rental agreements between tenant and tenancy. In this contract, the tenant fee is free, but the tenant owes their obligation to secure the condition of property. It means that the tenant has to prevent graffiti and structural destruction instead of free cost of living. Some houses have already terminated this contract and the owners live in the house again. In 2013, sixteen contracts had been signed (Schlappa and Neill, 2013).

The last case is the case of ‘Cho’, which is material provision by the residents. In mountain areas of the city of Kawachi Nagano in the prefecture of Osaka, the accident of the car’s invasion to farm lands has happened because of too narrow unpaved road. Local residents asked the civil engineering office of the prefecture of Osaka in Tondabayashi to improve the situation. The officers designed the concrete-pavement road with 2m width and residents were involved in the construction works since January 2004. Some residents joined in voluntarily and others lent their own tractors because the road is a community road for them. This activity can save 85% of the total 10 million JPY estimated project cost. The office experienced a similar case in 2002, where the residents also provided the stone and wood as materials, so that the project cost became 0 JPY apart from hidden cost of salary for officers (Ishiguro, 2004).

As discussed above, prioritizing, clear relationship between benefits and burdens, and exchanging goods and service face to face, along with a physical labour force, materials and guarantees by public authorities will be exchanged for infrastructure service provision. Infrastructure managers can thus obtain the necessary capital to maintain their infrastructures without financial resources.

A prominent feature of infrastructure development in depopulating societies is a decline in the number of users and also a decline in revenue. Non-monetary procurement of the necessary capital for infrastructure development will be inevitable and is likely to consist of sustainable infrastructure development.

10.4.1.5 Collaboration with several stakeholders and development of comprehensive sustainable regional development plan

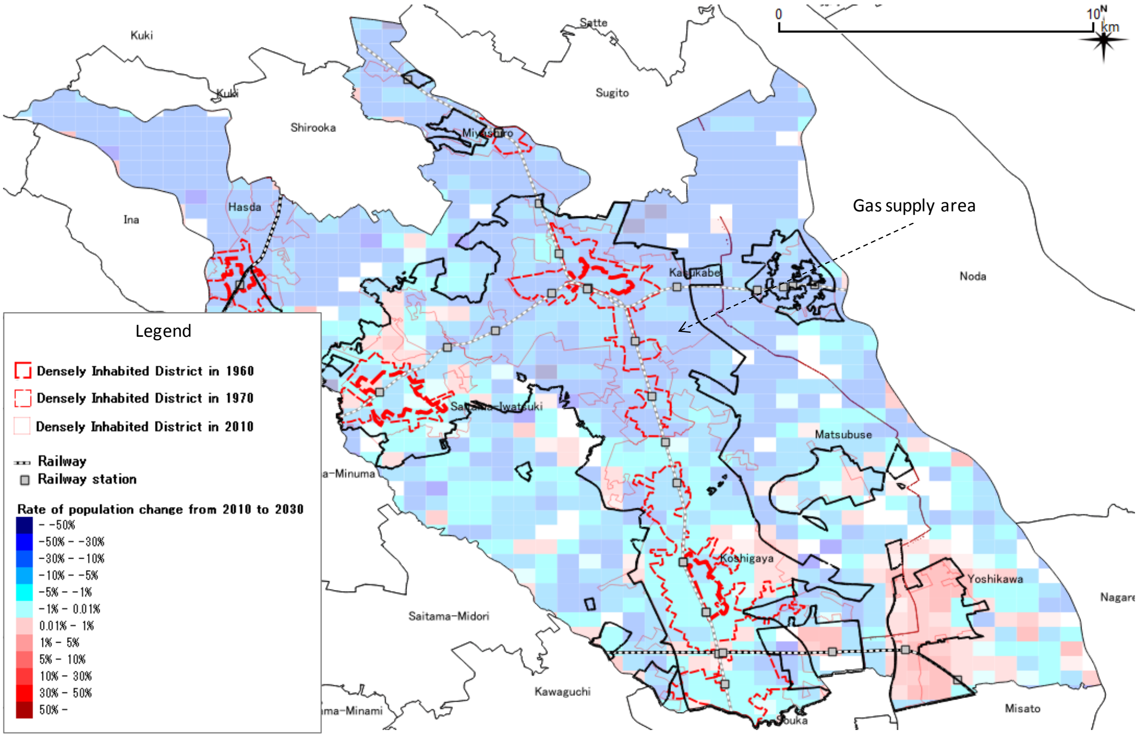
Before discussing the main issue of this subsection, one case study on gas supply network infrastructure and household decline in the suburb of Tokyo (Uemura, 2014b) is introduced. The case study area (Figure 109) is located in the suburb of Tokyo metropolitan and in the eastern part of the prefecture of Saitama. The Tosai Gas is the gas distributer for this area. This time, Tosai Gas provided the map information of Gas distribution pipeline and middle pressure gas transport pipeline data.

Source: National Land Numerical Information Data (City Areas (surface))

Figure 109 Tosai-gas gas supply area in the prefecture of Saitama in Japan

The population and the number of household in 2030 in each 500m mesh was projected by the author following the cohort analysis method for population projection by the national institute of population and social security research (IPSS) (National Institute of Population and Social Security Research, 2013; National Institute of Population and Social Security Research, 2014). In Japan, there is no spatial data on the urban area in 1960 because the urban planning act was introduced in 1965 and before the introduction; the government, therefore, didn’t have to prepare the spatial information of urban boundary. In order to know where is the old town in the current urban area, the spatial boundary of densely inhabited district (DID) based on the result of the National Census of Japan in 1960, which is the oldest DID, should be used.

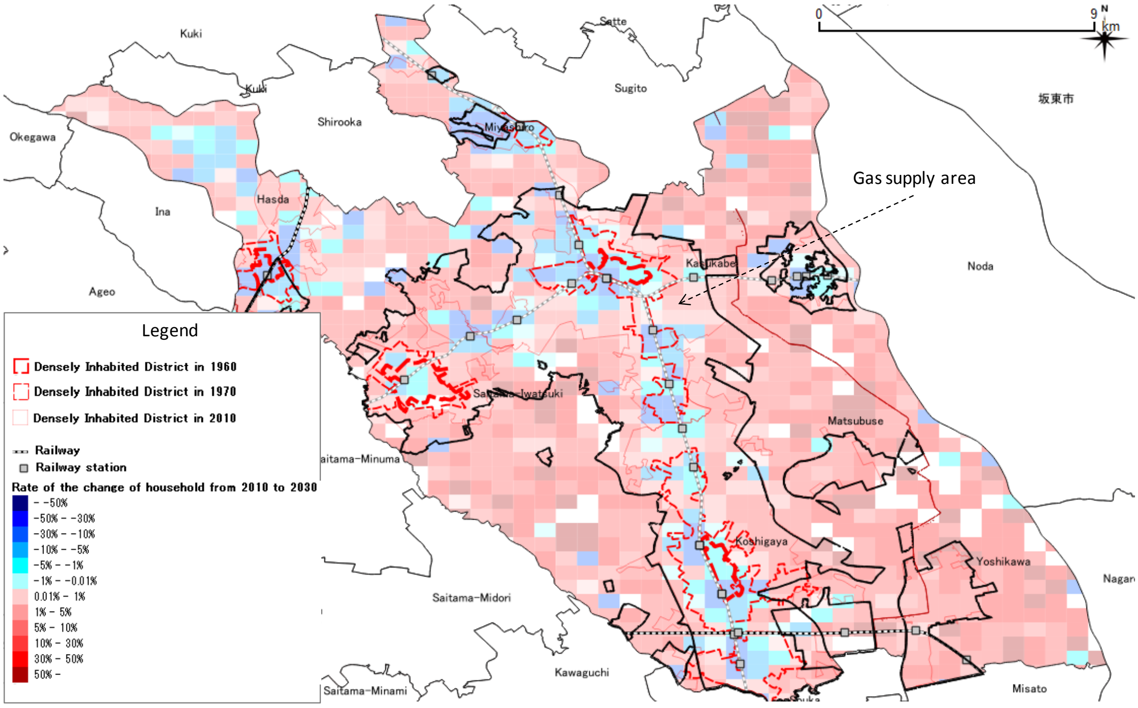
The most of mesh will lose the population by more than 10% between 2010 and 2030 (Figure 110). According to the overlay analysis between projected population in 500m by 500m mesh and DID boundary in 1960 (Uemura, 2014), it could be found that the old town in the suburb is the area of population decline. Those areas are also along the railway and near the station.



Source: National Land Numerical Information Data (City Areas (surface), Densely Inhabited District (surface), Railways (line)), National Institute of Population and Social Security Research (2013)

Figure 110 Population Change from 2010 and 2030 in Tosai-gas gas supply areas and historical Densely Inhabited District (DID)

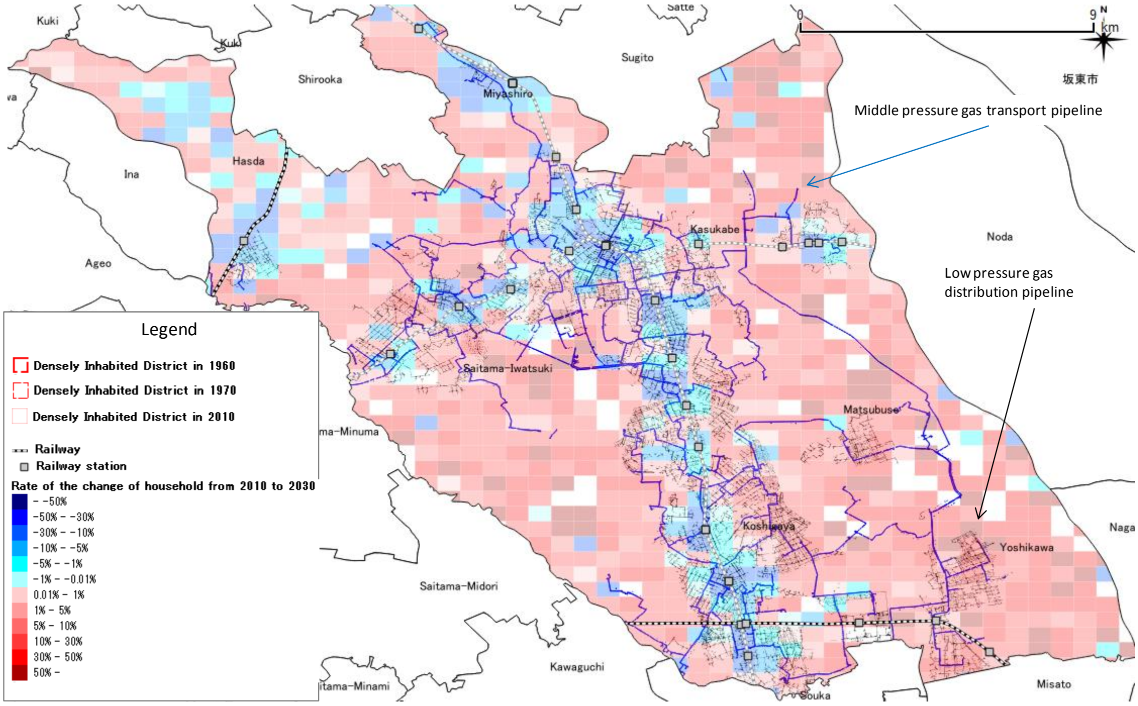
The picture of household change shows more extreme results (Figure 111). The decline in the number of household tends to be observed only near the station. Those areas are almost within the DID boundary in 1970. The perforation is a typically pointed out type of demographic change in depopulating areas in the world, but the situation in these areas are different. This is because the urban development in this area has started from the railway station and then has been sprawling, so that the ageing and decaying urban areas are likely to start from the station again, where the central district of each area.



Source: National Land Numerical Information Data (City Areas (surface), Densely Inhabited District (surface), Railways (line)), National Institute of Population and Social Security Research (2013) and National Institute of Population and Social Security Research (2014)

Figure 111 Household Change from 2010 and 2030 in Tosai-gas gas supply areas and historical Densely Inhabited District (DID)

These areas with household decline has more densely gas distribution pipeline network (Figure 112). The gas distribution network has been developed all over the old DID areas and the demolition and downsize of it are highly likely to affect gas distribution in those areas. This is because the decline in the number of household will happen, but it is not equal to disappear all households from the areas. Naturally, the middle pressure gas transport pipeline supplying the gas for the gas distribution line cannot be demolished until all gas users will be disappeared. This will result in the burden for the gas company because the maintenance cost per pipeline length or per user will increase in contrast to the gas sales revenue will decline



Source: National Land Numerical Information Data (City Areas (surface), Densely Inhabited District (surface), Railways (line)), National Institute of Population and Social Security Research (2013) and National Institute of Population and Social Security Research (2014), Tosai-gas material (gas pipeline map)

Figure 112 Household Change from 2010 and 2030 and distribution of gas supply pipeline in Tosai-gas gas supply areas

This case study area is not recognised as the New Town like Tama areas, but sprawling areas along the railway. The household decline is the lately happened phenomena after population decline after ageing and retirement. It means that the railway passenger decline is happened before the consumption decline of utility service. The railway company may develop or redevelop the areas near station in order to cope with the passenger decline and to intend to increase potential passengers. A railway company often behaves as property developers in Japan. In some case, this development policy by the railway company causes the sprawl of urban area because they usually look for lower price lands for housing development. Recently, the deterioration of the high street in front of stations has happened and redevelopment of those areas has been conducted. When the railway company redevelop the depopulating areas, it also enables to help other utilities' companies. It means that focusing on only one type of infrastructure is useless when sustainable infrastructure development and management is discussed. Of course, there are some timescale differences, but railway, water supply, waste water management, gas and electricity are all network or point-network types of infrastructure, and so once the gas infrastructure is damaged by the regional demographic change, the other infrastructures will also be damaged the same way. Therefore, all kinds of infrastructures have common destiny.

On the other hand, the recently introduced policies for coping with impacts of population decline on infrastructure development and management have taken a sector-wide approach. Therefore, the policies are separated vertically by type of infrastructure and have no correlation with each other. In addition, there is no special policy tying between each type of infrastructure and urban planning or land use planning at the central level.

In this regard, telephone interviews were tried to the city of Kaskabe and the city of Koshigaya, but answers were not expected. Those cities only developed or are developing the obliged comprehensive plan for public facilities or long-term plan for other infrastructures. Furthermore, no cooperative activities have been conducted between private infrastructure companies and local government.

The relationship between infrastructure and land use is out of scope for this thesis. One thing, however, can be pointed out, that is some business regulation on infrastructure obliges the business entities to supply infrastructure services to users without any exception. For example, article 15 of the water act regulates the water bureau to provide a compulsory water supply to users. This regulation sometimes contributes to the sprawl of urban development even in a depopulating society.

This is the big issue of how low cost regional development can be achieved given the existing infrastructure in a depopulating society. For discussing this issue and developing mitigation solutions, further research on the relationship between sustainable infrastructure development and sustainable land use development should be discussed in the future and the regulatory reform of infrastructure business should also be reviewed.

10.4.1.6 Summary

Table 81 shows a summary of the discussion results on by-product impacts on the four aspects of each countermeasure discussed above. Generally speaking one countermeasure will be presented for each impact, considering the main effects of the countermeasures, regardless of negative side effects.

Infrastructure managers are expected to develop a cocktail of countermeasures to conduct appropriate and sustainable infrastructure development and management in a depopulating society by exploring the strong and weak points of each set of countermeasures because the wrong countermeasure can create a much worse situation and may be irreversible.

Not only developing individual countermeasures, but also planning and management of sustainable infrastructure is strongly required.

Table 81 Reflected impacts on the other aspects

<table>
<tr><td rowspan="2">Four aspects</td><td rowspan="2">Countermeasure</td><td colspan="5">Reflected impacts on the other aspects</td></tr>
<tr><td>Social</td><td>Engineering</td><td>Environmental</td><td colspan="2">Economic</td></tr>
<tr><td rowspan="2">Social aspect</td><td>Downsizing</td><td>-</td><td>∆Some of building cannot be demolished partially.</td><td>-</td><td colspan="2" rowspan="2">○Contribution to reducing maintenance and replacement costs</td></tr>
<tr><td>Reconfiguration/merging and abolishing</td><td>×Decline in the infrastructure service provision such as accessibility</td><td>-</td><td>∆Deteriorating landscape owing to derelict buildings and structures</td></tr>
<tr><td rowspan="5">Engineering aspect</td><td>Decline in the service level</td><td>×Increase in potential risk of accident</td><td>-</td><td>-</td><td colspan="2">○Reducing per capita maintenance costs</td></tr>
<tr><td>Modular and using pre-cast concrete parts</td><td>○Easily following demand change</td><td>○Improving work environment by contractors and engineers</td><td rowspan="2">○Reducing construction wastes and new material' consumption using reused parts</td><td>○Cost reduction to physical development amount enabled by mass production</td><td rowspan="2">×Downsizing construction material industries like cement, and reducing job opportunities of skilled workers, then negative impacts on regional economy</td></tr>
<tr><td>Reusing parts</td><td>○Able to maintain the capability of service provision by infrastructure</td><td>○Easily standardizing construction works and keeping safe</td><td>○Cost reduction by reusing parts compared with physical infrastructure development amount</td></tr>
<tr><td>Short term rebuilding</td><td>○Keeping safe because of rebuilding before deterioration</td><td>○Increasing technology transfer opportunities</td><td>∆Increasing in resource consumption without reusing and recycling</td><td colspan="2">∆Increase in costs without reusing and recycling</td></tr>
<tr><td>Asset management</td><td>○Securing safety</td><td>∆Decrease in the opportunities of technology transfer but standardized technologies</td><td>-</td><td colspan="2">∆Increase in per-capita costs coming from maintaining low demand infrastructure</td></tr>
<tr><td>Environmental aspect</td><td>Reuse/Recycle</td><td>-</td><td>○Promoting design technology based on reusing and recycling</td><td>-</td><td colspan="2">∆Enabling cost reduction by regional resource circulation model</td></tr>
<tr><td rowspan="3">Economic aspect</td><td>Tax allocation system</td><td>○Able to maintain minimum level of infrastructure service provision</td><td>○Realizing appropriate maintenance of infrastructure</td><td>○Preventing environmental deterioration due to promoting demolition</td><td colspan="2">-</td></tr>
<tr><td>Private finance initiative</td><td>-</td><td>-</td><td>-</td><td colspan="2">∆Increase in user charge if not reducing costs by efficient management by private sector</td></tr>
<tr><td>Public private partnership</td><td>○Able to maintain minimum level of infrastructure service provision</td><td>○Able to maintain minimum level of infrastructure service provision</td><td>-</td><td colspan="2">-</td></tr>
</table>

Note: ○ is positive repercussion effect, ∆ is positive or negative repercussion effect up to conditions, × is negative repercussion effect, and - is no effect.

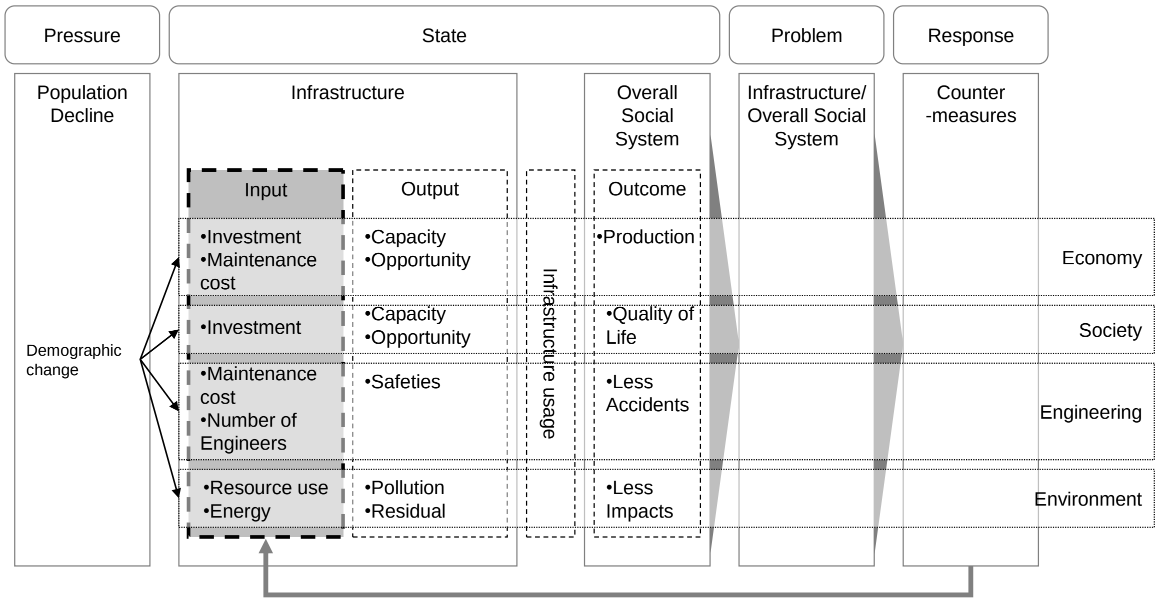
10.4.2 *SUSTAINABLE INFRASTRUCTURE DEVELOPMENT AND MANAGEMENT AND SUSTAINABLE DEVELOPMENT INDICATORS (SDIS) ON INFRASTRUCTURE*

When considering sustainable infrastructure development and management in a depopulating society, the following idea is suggested because the sustainability of infrastructure development and management is on a weak sustainability, which means that infrastructure managers have to consider the trade-off balance between the economic and other aspects. Thus, when the current service levels of the infrastructure are given, in order not to increase the economic burden per capita more than necessary in accordance with the decline in the demand for infrastructure services due to population decline, phasing out the capacity of infrastructure service provision at certain times will be required. At this time, we should remember that the economic and social aspects are considered as potential trade-offs, but the engineering aspect and the environmental aspects can be considered as constraints.

In order to monitor the realization of sustainable infrastructure development and management, the sustainable development indicators for infrastructure development and management (SDI for infrastructure) can be considered to be useful. The Organization for Economic Co-operation and Development (OECD) has already recommended using sustainable development indicators based on the Pressure-State-Response (PSR) model for monitoring environmental aspects (OECD, 1999). The diagram in Figure 4 is a possible example of the application of the PSR model for sustainable infrastructure development.

Figure 113 adds the stage of 'Problem' to the original PSR model by OECD because it can be considered that the state should be divided into an ordinary situation and a problematic situation, in which residents or users may experience any risk or threat in using the infrastructure. Also, the balance between multiple aspects of sustainable infrastructure development and management can be thought of as important in that the indicators should be interlocked. For example, and as described above, one countermeasure links to multiple aspects of infrastructure sustainability. Accordingly, when we consider the side-effects of countermeasures for realizing infrastructure sustainability, interlocked indicators for multiple aspects are necessary for monitoring purposes, as shown in Figure 4. In addition, the indicators in the State phase and in the Problem phase are expected to link to demographic change or countermeasures. These linkages enable infrastructure managers to conduct dynamic management of the sustainable infrastructure development and management using the results in chapter five.

The following diagram (Figure 113) is only a concept model of the sustainable development indicators for infrastructure development and management. It could be developed considerably in further research.



Source: Uemura and Mourato (2008).

Figure 113 Concept model of developing sustainable development indicators for infrastructure management

In the case of monitoring using the SDI for infrastructure, the criteria of sustainable infrastructure development and management should be determined. The definition of sustainable infrastructure development and management can be considered as the balance of indicators between the economic aspects and the other aspects and will not be worse than now, based on the weak sustainability criteria. For the purposes of this analysis, the integrated indicator for all other aspects but the economic aspect is expected to be developed.

An Analytical Hierarchy Process (AHP) is often applied when multiple and different dimension indicators are synthesized. AHP conducts comparative assessment on two objectives, each of which repeatedly uses a pair wise comparison, in order to determine the relative assessment values. The integrated indicator ($I_{synthesis}$) is synthesized from the indicator of social aspect (I_{soc}), the indicator of engineering aspect (I_{eng}), and the indicator of environmental aspect (I_{env}). The estimation process will produce the weight value for synthesis as follows: the weight on the social indicator (w_{soc}), the weight on the engineering indicator (w_{eng}), the weight on the environmental indicator (w_{env}). The integrated indicator is calculated in terms of the following formula (10.1):

$$I_{synthesis} = w_{soc}I_{soc} + w_{eng}I_{eng} + w_{env}I_{env} \tag{10.1}$$

where, $w_{soc} + w_{eng} + w_{env} = 1$

In order to ensure the sustainability of the weak sustainability standards, the ratio between the integrated indicator ($I_{synthesis}$) and the economic indicator (I_{econ}) should be satisfied with more than one as formulated in the formula (10.2):

$$\frac{I_{synthesis}}{I_{econ}} \geq 1 \tag{10.2}$$

Figure 114 summarizes the above mentioned management process. The assumed management process for realizing sustainable infrastructure development will follow the steps shown in Figure 114. After infrastructure development, monitoring using SDI for infrastructure is conducted, then the condition of infrastructure sustainability can be assessed using the assessment formula. The results of the sustainability assessment will suggest the vulnerability of the sustainability infrastructure. The infrastructure manager will then develop countermeasures based on the results and conduct them. Again, the sustainability assessment will be conducted after conducting countermeasures. It can be considered as important that this series of processes should be executed in order to achieve sustainable infrastructure development and management.

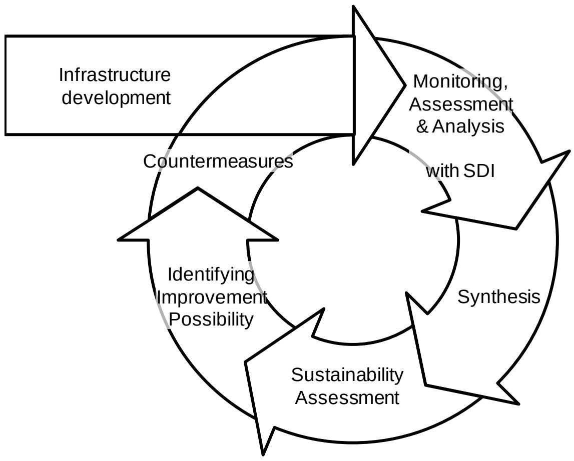


Figure 114 Circle flow of sustainable infrastructure development and management

As mentioned above, it is possible that SDI will become an effective tool of infrastructure management in a depopulating society. SDI, however, only visualizes the state-change of the quantity or quality of infrastructure service provision, and is, therefore, used for monitoring, but cannot be used for decision making of the level of infrastructure service provision. This criterion of what extent of infrastructure service is provided should be decided exogenously. The decision making threshold on SDI itself is about the consensus building issue between infrastructure managers and users. SDI is just an auxiliary tool. It can only support this discussion and will be a monitoring tool for assessing the achievement of the built consensus on infrastructure service provision in a policy evaluation or project assessment.

10.4.3 Wise monarch and Consensus building

As discussed in chapter nine, it is found that the users of infrastructure may not rationally conduct decision making on long term infrastructure development and management over their life expectancy. Given this premise, the politician elected by a democratic process based on public opinion may not also be rational from the sustainability perspective on infrastructure development and management.

In the cases of 'So', 'Yo', and 'Cho', the mayors in the villages of Shimojyo and Achi could draw on the cooperation of voluntary labour from the residents. On the other hand, the Kawachi Nagano case provided the labour force for construction works by the government officers, and in the Yubari case, the private stakeholders like civil group members decided by themselves without local politicians and local government officers.

In contrast, the residents and government officers who don't have so much experience to conduct infrastructure development and management sometimes become resistant in the community and organization.

When the local government attempts to reorganize public facilities, the biggest resistance is residents (users of the facility) in some cases. For example, Suginami ward in Tokyo attempted to abolish the integrated facilities of social care, child care and a meeting room constructed in 2004 located near the station of Ogikubo by 2018 and will reallocate the 6,300 m2 for the current Ogikubo tax office and civil servant quarters owned by the Ministry of Finance, and will then develop a special nursing home for the elderly with 200 people capacity. The users were against this plan and collected more than 1,000 signatures to resist this plan. In the other case of Nagayama in the Tama New Town in the city of Tama, the Nishi Nagayama junior high school, which is 20 minutes walking distance from the station, was closed but was still opened to the residents temporarily. The city of Tama decided that the building of the school would be demolished to develop the outpatient facilities of people with disabilities on that land. For this policy, the existing users collected 700 opposing signatures and then petitioned the local assembly (Anonymous, 2014d). These oppositions could be observed in the preliminary stage of the Altena case and the Shimojyo case. How to go beyond this situation is the essential issue for the achievement of sustainable infrastructure development and management.

The resistance in the local government is also a very big issue. The city of Hadano is one of the most advanced municipalities in terms of public facility management in Japan. It has already introduced the dedicated department on reorganization of public facilities since 2008. The city developed the plan of reorganization in 2011, and launched the policy to reduce about 30% of floor area over the next 40 years. The city, in this context, tried to invite the postal office into the social care facility, but the charged department was quickly against this idea. The reason for resistance was that there was no precedent case of listing signs of the post office in the front of the social welfare facilities (Anonymous, 2014c).

How to persuade those resistors and convert them to supporters is the further research task. The town of Miyashiro has already succeeded in persuasion. The town rents the town-gymnasium to the school corporation of Shohei gakuen. This is following the policy of reconfiguration of public facilities developed in November, 2011. The school corporation pays 9 million JPY per annum as maintenance cost and also pays 10 thousand JPY per month as rental fees. When the school doesn't use the facility, residents can also use it. For this conversion, the town picked up one thousand residents randomly and held a workshop to discuss what function should be retained for residents to use the facility easily and comfortably when merging and abolishing public facilities. In order to build consensus, the town held 40 workshops (Anonymous, 2014d).

Nowadays, the policies to achieve sustainable infrastructure development and management in the context of population decline are developed by the central government on the assumption of support from the central government to local government. In particular, the technical advice is provided from the central government to local government. For example, the MLIT has obliged local government to conduct regular inspection (visual proximity inspection, palpation if needed, and hammering tests) on roads, bridges and tunnels since 2014, and also introduced four stage standard assessment criteria ('health', 'follow-up', 'necessary precautions', and 'urgent action') every five years. The upper government like the central and prefectural government can order municipalities to regulate traffic in the case of very harmful situations. In addition, the MLIT is establishing a new subsidy scheme to support road maintenance work in 2015 (Anonymous, 2014a).

In this way, the central government, the wise mayor (politician) in local government, as well as highly aware local government officers and a private person have acted as a wise monarch and produced the best practices on the sustainable infrastructure development and management in depopulating areas. In other words, rather than contrasting composition between wise monarch and democratic decision making, it can be concluded that the hierarchical decentralized voluntary autonomous decision-making system (exercise of leadership) by stakeholders according to the spatial spread of infrastructure service provision is required to achieve the sustainable infrastructure development and management. The government has to encourage multi-layer leadership and not to inhibit this type of activity, but rather to develop a support policy and financial supporting system.

Although irrationality of decision making by residents was introduced in chapter nine, the different results may be collected from residents in the best practice regions. If the residents can change their mind because of attendance of voluntary infrastructure development and management at the community level, the researcher should be mindful of such a possibility when they conduct the survey for residents. Also, in such a case, the residents' involvement in the community level infrastructure development and management will result in securing rational decision making on sustainable infrastructure development and management. For this, the smaller municipalities may find it easier to achieve sustainable infrastructure development and management than the bigger urban areas because the residents' involvement is much easier in the small municipalities suffering from severe population decline now.

10.5 CONCLUDING REMARKS

This series of studies consists of discussions about how population decline can threaten society, with particular reference to infrastructure development, what type of impacts and issues population decline leads to and what type of countermeasures can be applied, in contrast to the situation of irreversible resource consumption caused by population growth in Japan. With regard to population decline, a number of comprehensive and quantitative studies have targeted many types of infrastructure which can be affected, using the framework of sustainable development in this study.

As a result, findings about the impact of population decline on infrastructure development and management can be made and confirmed. In addition to this, some countermeasures against the impacts and issues of population decline on infrastructure development and management are suggested based on a series of research results apart from this study. These prescriptions are not only countermeasures for each aspect, but also cover concepts of management and explain policy and project ideas for infrastructure managers.

The issue of population decline is not yet a serious problem in developed countries like Japan and Germany, but may soon appear in a developing country like China. It is expected that the results of this study will identify some of these future issues in detail.

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CHAPTER 11: CONCLUSION

11.1 SUMMARY OF THESIS

The background to the series of this study is that very few previous studies have been concerned with how population decline threatens society and infrastructures and what kinds of problems will result in population decline and how infrastructure managers can cope with the issues in the context of irreversible resource consumption by population growth, that is typically assumed in the discussion of general sustainability. Few existing case studies and a small number of mail surveys and comprehensive and quantitative studies for all types of infrastructure can be found in Japan, or even in the rest of the world. This study has, therefore, attempted to clarify the actual issues and impacts, as well as suggesting countermeasures for those issues of population decline related to sustainable infrastructure development and management, considering the network character and sustainability of various types of infrastructures.

The results from this study, interestingly, suggest that some of the issues and impacts of infrastructure development and management cannot be related to population decline. In addition, from the infrastructure user's standpoint, there is no differentiation between the requirement of the service level for infrastructure development and management in depopulating and non-depopulating areas. In this way, this study has added some interesting findings to the knowledge stock established by previous researchers.

Furthermore, in the concluding chapter, the countermeasures and management process ideas for realizing sustainable infrastructure development and management which have already been discussed in other studies were introduced. These countermeasures cover not only individual engineering solutions, but also management frameworks and will hopefully provide concrete and realistic policies and business ideas for infrastructure managers. Some of the ideas presented as countermeasures have already been in practical use.

On the other hand, the phenomenon of population decline is not only occurring in Japan, but also in other countries like Germany and China. Emerging countries are facing rapid population growth, which is a cause of the issues discussed in this study. It is not certain that knowledge from this study can be applied to other countries instantly, but it is expected that the results can be shared to help conduct comparison studies based on this study.

11.2 POLICY RECOMMENDATIONS

In Japan, the many policies expecting to contribute to sustainable development of infrastructure have been introduced since 2009. The promotion of asset management of infrastructure, promotion of demolition, and reviews of inspection standards have been introduced by the central government and the conventional grant-in-aid from local allocation tax is still functioning. Accordingly, the countermeasures from economic and technical perspectives are steadily performed. In addition, residents' involvement in sustainable infrastructure service provision and maintenance of infrastructure service quality, have already started in the high awareness municipalities. Furthermore, the best practice of demolition of public facilities (mitigating landscape issue) and reuse of parts of infrastructure (resource consumption saving) from the environmental perspective are introduced in the White Paper in Japan (Ministry of Land, Infrastructure, Transport and Tourism, 2014). Moreover, the central government makes municipalities develop a comprehensive management plan on public facilities and a long term plan for infrastructures. These activities are welcomed to promote sustainable development on infrastructure in the context of population decline, but the only fault is separate policies by each ministry. Of course, background consciousness is shared and the countermeasures are optimized for each infrastructure type. As pointed out in this thesis, it is difficult to find the general and direct relationship between demographic change and the problems of infrastructure development from the results of quantitative analysis. Along with reviewing the best practice in advanced municipalities, precautional policy action by the mayor and municipalities becomes important to manage a priori decided path for infrastructure management in the context of population decline. In these regards, the recently introduced policies by the government of Japan should be followed by the foreign government officers.

Beyond this practical aspect, any level of government officers should decide either to accept shrinkage or counteract shrinkage in order to develop a vision for the whole infrastructure development and management policy (Verwest, 2011; Rink et al., 2012) if they are to deal seriously with the issues of infrastructure development and management in the context of population decline.

Japan has not accepted any immigrants apart from technical workers like nurses and trainers in agriculture and so on, and the population decline will continue for 20 years; even if the birth rate rises above 2.0, accepting shrinkage is an inevitable choice all over Japan, while, of course, each region can have a little more variety of choice.

When choosing this option, the cost of demolishing infrastructure should also be kept in mind by the government officials. If the demolition costs and negative side effects from the decline in infrastructure service provision are more than the improvement of landscape and future reduction of the maintenance cost, doing nothing will also become a better choice. Actually, it can in time demolish unused infrastructure when the infrastructure manager observes more negative side effects than the cost of demolition. Delaying decision making is surely no worse a policy choice in this context, while, of course, precautional decision making is more praised.

Simultaneously, the effective countermeasures are frequent review of infrastructure service level and provision, residents' involvement, new technology development to reduce maintenance costs and replacement investment, developing long-term infrastructure and management to position various countermeasures, as well as developing cash management for future infrastructure development and management based on objective information on the conditions of infrastructures. Not only central government officers, but also each infrastructure manager is expected to be aware of these points and to act utilizing those countermeasures. Of course, some municipalities with a history of over investment to infrastructure will face more severe financial constraint, but what to do is, unfortunately, the same. They have to take more care of 'voting by foot' by residents, and more serious efforts are expected in those municipalities to prevent too much burden on residents.

11.3 Further Research Tasks

This subsection gives further research tasks and prospects for them.

11.3.1 Spatial analysis for infrastructure reconfiguration

This study has conducted an analysis of what factors affect sustainable infrastructure development and management in depopulating regions using municipality level data. On the other hand, other research results suggest that infrastructure users should be allowed only 30 minutes to use infrastructure services for any land transport such as cars and walking (Nomura Research Institute, 2008). This time constraint is not the same as that of the boundary of municipalities. It means that location analysis or other types of spatial analysis on the location of infrastructure may be necessary for the reconfiguration of the infrastructure in order to cope with issues of population decline and infrastructure management.

As in the previous case studies on the shrinking cities in eastern Germany and on the city of Okayama, perforation is the typical style of population decline in urban areas (Uemura and Uto, 2010). This also suggests the necessity for conducting micro level analysis using GIS data on demographic change and infrastructure service provision. Actually, very partial case study results with high spatial resolution of 500m by 500m were introduced in chapter ten on the spatial analysis between demographic change and network infrastructure. Such a high spatial resolution analysis is required in further research.

In Japan, it is hard to find spatial quantitative analysis on the reconfiguration of the infrastructure, but the government of Japan has already published point data and network data sets of the infrastructure and 500m by 500m mesh demography data sets. Future research should utilize those data sets in conducting further studies.

11.3.2 SUSTAINABLE DEVELOPMENT INDICATORS ON INFRASTRUCTURE SUSTAINABILITY

The Ministry of Environment in the government of Japan has already published statistics on the environment based on the PSR model[13]. As mentioned before, the SDI for infrastructure based on a modified PSR model is expected to be used for condition based monitoring to achieve sustainable infrastructure development and management. The ministry of Land, Infrastructure, Transport and Tourism, of course, gives many statistics to the public, but does not have any framework for sustainable infrastructure management. The cabinet office in the government of Japan also provides

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[13] http://www.env.go.jp/en/statistics/contents/index_e.html

other estimation results on infrastructure development and management called ‘Nihon no Syakai Shion’ (Japanese infrastructure) every few years (Cabinet Office of Japan, 2007). For developing the SDI for the infrastructure, these statistics and estimation should be reorganized appropriately.

11.3.3 Consensus building and new public-private partnership

According to the results of the analysis in chapter nine, people cannot rationally decide on long-term infrastructure development when most users will be dead. This means that a democratic process that makes decisions on sustainable infrastructure development and management may lead to errors in decisions. Therefore, the ‘wise Monarchy’ is expected to promote sustainable infrastructure development and management in depopulating societies. In fact, there is no particular ‘wise Monarch’ at all. Actually, various types of leader could be found in the case studies, from the mayor to the leaders of civil groups. Those infrastructure managers are expected to play the role of ‘wise Monarch’, when they ask users to accept the levelling down of infrastructure service provisions and to cooperate with infrastructure development and management, together with infrastructure managers. For this purpose, consensus building becomes very important, but before that infrastructure managers have to clarify recognition gaps between the information delivered by infrastructure managers and the understanding of that information by users. The service gap analysis is expected to become useful to clarify this gap.

Service gap analysis was originally developed for analysis of service provision by private companies for their customers. The recognition gaps between service providers and service consumers, the misunderstanding of needs of service consumers by service providers, any errors happening in the service provision process, and the causes of service gaps, can be analyzed by this method (Zeithaml, Parasuraman and Berry, 1990). This analytical method has also been introduced in the international infrastructure management manual for infrastructure managers (New Zealand Asset Management Support, 2011).

On the other hand, infrastructure users were previously infrastructure developers and managers as well in our history. Levees and ponds for agriculture and flood management, or tunnels for irrigation, roads, bridges and many other examples of community infrastructure were developed using local materials donated by local residents, as well as labour forces and engineering knowledge donated by landlords. ‘Man no ike’ and ‘Hakone Sosui’ are typical examples in agriculture. Nowadays, the same types of infrastructure development and management can be observed in highly depopulating areas like the town of Shimojyo and the village of Sakae in the prefecture of Nagano. Highly depopulating municipalities do not have enough money to conduct sufficient infrastructure development. The municipalities ask the local people to give their work to conduct the infrastructure management in their living areas, as mentioned before in this concluding section.

Once population decline becomes more severe, the governmental sector may also lose their financial power to support the region, so it is essential to develop a non-monetary based economy for achieving sustainable infrastructure development. This may result in a lower GDP and a downsized local economy, but may substantially sustain physical infrastructure service provision and its functions. This change is easy to observe when the social capital of the community is very strong. In other words, the sustainability of community and the sustainability of infrastructure are different sides of the same coin.

Nowadays, many voluntary activities are undertaken to maintain infrastructures. Without being bound to the current form, initiatives whereby the users themselves are involved in infrastructure management should be promoted, and future research in promoting it is expected.

11.4 CONTRIBUTIONS

The novelty of this series of studies is repeatedly pointed out, but the last point that should be stressed is as follows: infrastructure development usually follows a demographic change in the stage of population growth, although infrastructure managers try to develop good plans for infrastructure development. In the process of population decline, the same situation will occur. The errors of infrastructure development in the developing stage can easily be fixed naturally in certain years when the errors are highly likely to be enlarged in the process of population decline. Of course, as mentioned above, some delayed decision making is allowed for infrastructure managers because the infrastructure capacity should be downsized after the demand for the infrastructure service provision completely disappears, but too late decision making causes the more serious situation because of lack of users who can share the various types of burden of infrastructure development and management. As a result, quality of infrastructure service, namely per-capita anything will deteriorate. Accordingly, infrastructure managers must be asked to conduct the more prudent management of their infrastructure.

One solution to the issues of population decline on infrastructure development and management is to replenish the population, but as pointed out in the introduction, Japanese people would not be favour of immigrants being brought in from abroad. The regional rapid population decline has sometimes resulted from changes in the age structure of these areas. For example, we could observe a high concentration of particular cohorts in the new town areas because of its development history. The new towns in suburbs of metropolitan cities have found it hard to recover their lost population in recent years and this type of population decline may cause issues of infrastructure management. To mitigate such a situation, one easy solution can be proposed. It is very simple but involves the developers taking more time to develop the areas of mixed settlements by using various types of households and age groups of people. Now many development projects are conducted in developing countries, but they will need to learn this point.

Population decline is the immediate concern and there are still few really effective solutions. More future research on this topic is needed to achieve a sustainable society supported by a sustainable infrastructure, even in depopulating areas in the future.

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APPENDICES

ANALYTICAL CODE FOR THE CHAPTER 8

The actual code for analysis in “R” is as follows:

```
# Reading the package of R

library(Design)

library(stats)

#Reading the data for estimation

PDR5<-read.table("E:/env_pf_PDR5_20120108.txt", header=T)

#Choosing variables using forward stepwise with AIC

PDR5.int <-glm(Impact~1,PDR5,family=binomial)

PDR5.fstp <-
step(PDR5.int,.~PDR5+PopSize1000persons+Elderly+ND+SD_ER+SD_AB+SD_AT+SD_FC
+SD_DI+Dec_Pat+Areakm2+DIDPop+HabitableA+PrimeIndustry+Schools+Housing+Facilitie
s+Parks+Tanks+Transport+Road+ADisaster+re_P.Service+MA_Facilities+Contracout+Downsi
ze_Finance+Re_Salary+eGov+Not_Enough+ReveExpend+DebtRepay,direction="forward")

summary(PDR5.fstp)

#Conducting estimation and calculating fitness and AIC of models

resultPDR5<-lrm(Impact~Elderly+DIDPop+Housing+eGov+SD_DI, data=PDR5)

AICresultPDR5<-glm(Impact~Elderly+DIDPop+Housing+eGov+SD_DI, family=binomial,
data=PDR5)

resultPDR5

AICresultPDR5
```

QUESTIONNAIRES FOR INFRASTRUCTURE MANAGERS

The following questions are the English translations of the questions in the mail survey. The original questions in the survey were written in Japanese.

Guidance Note for Answers

＜Anticipated respondents＞

We assume that public officers who are in charge of planning in your municipality will answer this questionnaire.
Please forward this to the appropriate department if necessary.

＜Assumed answer time, in minutes＞

Approximately 30 minutes

＜Notes for Answers＞

- Please answer the following questions frankly in accordance with respondents' recognitions or opinions if your municipality does not have official answers.
- Please consider that issues concerning population decline in your municipality are to be understood in the broad and general sense. In this questionnaire, policies which consider demographic trends and distributions in some way must be regarded as the policies for population decline. For example, a merger or abolition of public facilities which considers demographic distribution should be included in policies for mitigating population decline's impacts, even though the main purpose of such a merger or abolition may for instance have been improvement of the municipality's budgetary situation.

Deadline：5th September, 2008 (Friday)

■Please let us know the name of your municipality, and the address of respondents or a representative for the respondents.

Name of municipality	Prefecture Municipality	
Respondent	**Department**	
	Name	
	Phone No.	— —
	E-mail	@

■If you wish to know the results of the survey, we will send summary of it to you by e-mail at the above stated address.

Would you like to have the survey results?	１．Yes ２．No

Structure of questions

I. Situation of population decline and countermeasures in your municipality:

Q１ Causes of population decline
Q２ Regional tendency for population decline
Q３ Situation of administrative reform

II. Overall situation of infrastructure development and management in the context of population decline:

Q４ Relationship between demographic change and investments for infrastructure
Q５ Consciousness of crisis in infrastructure development and management
Q６ Future policy of infrastructure development and management
Q７ Intention of introducing private finance
Q８ Relationship between the level of infrastructure management and the financial situation
Q９ Differentiation of the level of infrastructure development within the municipality

III. Each situation of infrastructure development and management in the context of population decline

Q10 Situation of infrastructure development and management by PD（education）
Q11 Situation of infrastructure development and management by PD (public dwellings)
Q12 Situation of infrastructure development and management by PD (life-related facilities)
Q13 Situation of infrastructure development and management by PD (water-related facilities)
Q14 Situation of infrastructure development and management by PD (transport)
Q15 Situation of infrastructure development and management by PD (roads)
Q16 Situation of infrastructure development and management by PD (emergency and disaster facilities)

IV. Problems caused by population decline and countermeasures:

Q17 Problems of increase in numbers of vacant houses and properties, and their countermeasures
Q18 Problems caused by new urban development, and their countermeasures
Q19 Problems caused by industrial infrastructure development, and their countermeasures

V. Others

Q20 Preservation condition of fiscal closing data
Q21 Open answer concerning impacts of population decline on infrastructure management

＜Definition of terms in the questionnaire＞

Terms	Definitions
Infrastructure	Publicly financed buildings: including schools, social care facilities, public dwelling etc., and public structures such as roads, emergency and disaster facilities, and water supply and waste water management facilities.
Infrastructure development	New investment, improvements of existing infrastructure and replacement: which are value-adding or function adding public works.
Infrastructure management	Maintenance and repair facilities: which are for sustaining infrastructure and are ordinary works, including engineering works, but in particular do not include investment and construction.
Allowance for investment	'Allowance' means that the municipality can afford to pay sufficiently for investment and policy-outlay paying compulsory expenditures.

I. Situation of population decline and countermeasures

Q1. The cause of population decline in your municipality: Please choose all appropriate options from 1) to 7) and tick in the blank box, ☐ like ☑. When answering 6) or 7) please provide your comment between the brackets.

1) Natural decline owing to a birth rate decline and ageing. ☐
2) Social decline due to leaving school and finding employment. ☐
3) Social decline owing to abolition of governmental branches. ☐
4) Social decline caused by abolition of public transport. ☐
5) Social decline caused by ending large public construction works. ☐
6) Social decline due to decline of major industry. ☐
   (Specifically:)
7) Others ☐
   (Specifically:)

→to Q2

Q2. Occurrence of population decline in your municipality:

SQ1. Please choose an appropriate answer from 1) and 2), and tick in the ☐ like ☑.

1) A part of areas within your municipality has lost its population. ☐ →to Q2
2) Your municipality has lost population evenly overall. ☐ →to Q3

SQ2. What types of areas have lost their population? Please choose all appropriate options from 1) to 9) and tick in the ☐ like ☑.

1) A settlement formed before the Second World War. ☐
2) A settlement formed between the end of the Second World War and the era of high economic growth. ☐
3) A settlement formed after the era of high economic growth. ☐
4) A town centre. ☐
5) A peripheral. ☐
6) A specific industrial area, but the industry has declined. ☐
7) A less accessible area for public transport. ☐
8) A less accessible area for public services such as medical, social care and educational services. ☐
9) Others ☐
   (Specifically:)

→to Q2

SQ3. Can you identify a difference of population decline within an area? Please choose all appropriate options from 1) to 5) and tick in the ☐ like ☑.

1) No differences within an area. ☐
2) A centre of an area is more severe. ☐

3) A peripheral part of an area is more severe. ☐
4) The part with less accessibility for public transports is more severe. ☐ →to Q3
5) Others ☐
(Specifically:)

Q3. Government reform activities in your municipality.

SQ1. What types of government reforms do you conduct? Please choose <u>all appropriate</u> options from 1) to 8) and tick in the ☐ like ☑.

1) Reviews of public services for residents. ☐
2) Reorganising and merging public facilities. ☐
3) Utilizing contracting out for operation and maintenance. ☐
4) Reduction of assets and debts. ☐
5) Reducing the number of public officers and their salaries. ☐
6) Promoting e-government. ☐
7) Others
(Specifically:) ☐

(1) to 7): →to Q3 SQ2)

8) Delaying the performance of concrete reforms. ☐ →to Q4

SQ2. What is the reason for conducting government reforms? Please choose <u>all appropriate</u> options from 1) to 8) and tick in the ☐ like ☑.

1) Reduction in tax revenues owing to population decline. ☐
2) Reduction in tax revenues owing to decline of main industries. ☐
3) Declines in transfer revenues from the central or higher level of government. ☐
4) Increases in expenditures owing to previous investments or improvement of public service levels. ☐
5) Mergers of municipalities. ☐
6) Policy of mayors. ☐
7) Policy of either the central government or prefecture. ☐
8) Others
(Specifically:) ☐

(1) to 8): →to Q4)

<u>II. Overall situations of infrastructure development and management in the context of population decline</u>

Q4. <u>Previously,</u> how did you control investments for infrastructure developments in the context of population decline? Please choose <u>all appropriate</u> options from 1) to 6), and tick in the ☐ like ☑. If you answer 5), please write the reason between the brackets and if you answer 6), please write the specific idea between the brackets.

1) Population decline has not been remarkable, so there has been no special consideration of population decline for infrastructure investment. ☐
2) Because of recognising the trend of population decline, the investment for infrastructure development has been reduced even though the municipality could have afforded not to ☐

→to Q5

do so.

3) Because of both recognising the trend of population decline and strict budgetary constraints, the investment for infrastructure development has been reduced . ☐

4) Although population decline has been recognised, infrastructure investment has been continued positively because the municipality can afford to do so. ☐

5) Although both recognising the trend of population decline and strict budgetary constraints have been recognised, infrastructure investment has been continued positively. ☐
(Reasons:)

6) Others ☐
(Specifically:)

Q5. This relates to consciousness of crisis in terms of future infrastructure development and management.

SQ1. Do you have a consciousness of crisis in terms of future infrastructure development and management? Please choose <u>only one appropriate</u> option from 1) to 5) and tick in the ☐ like ☑.

1)	Strong consciousness of crisis in infrastructure.	☐	→to Q5 SQ2
2)	Some consciousness of crisis in infrastructure.	☐	→to Q5 SQ2
3)	Not serious consciousness of crisis in infrastructure.	☐	→to Q6
4)	No consciousness of crisis in infrastructure.	☐	→to Q6
5)	Cannot say.	☐	→to Q6

SQ2. What types of crisis do you worry about specifically? Please choose <u>all appropriate</u> options from 1) to 7) and tick in the ☐ like ☑.

1) Strong budgetary constraints will not permit sufficient new investment. ☐
2) Strong budgetary constraints will not permit sufficient investment for replacement facilities. ☐
3) Strong budgetary constraints will not permit sufficient expenditure for repair and maintenance work. ☐
4) Lack of new investment for infrastructure will cause a deterioration of city and town. ☐
5) Lack of replacing investment will cause a deterioration of existing infrastructure. ☐
6) Lack of a maintenance fund will cause physical accidents resulting in injury or death. ☐
7) Others ☐
(Specifically:)

} →to Q6

Q6. <u>In the future,</u> how would you like to control infrastructure development and management in the context of population decline? Please choose <u>only one appropriate</u> option from 1) to 5) and tick in the ☐ like ☑.

1) Both investment and maintenance works should be reduced in proportion to population decline. ☐
2) Investments should be reduced in proportion to population decline, but maintenance works should be kept as active as possible. ☐
3) New investments should be reduced in proportion to population decline, but replacement and maintenance works should be kept as active as possible. ☐

} →to Q7

4) Despite population decline, investment and maintenance works should be continued. ☐
5) Others ☐
(Specifically:)

Q7. In terms of future infrastructure development and management, do you think private finance (PF) should be introduced in order to avoid budgetary constraints? Please choose only one appropriate option from 1) to 6) and tick in the ☐ like ☑.

1) PF should be introduced positively in all infrastructure types due to the limitations of municipality budget size. ☐
2) PF should be introduced in some types of infrastructure but not in the remainder. ☐
(Acceptable types:)
3) PF should be introduced only after clarifying the responsibility for allocation between government sectors and private sector. ☐
4) Infrastructure should be provided only by government; therefore, their management and development should be conducted within pubic finance capacity. ☐
5) Only, central government and prefectures, not municipalities, should have responsibilities to develop and manage infrastructure. ☐

(1)–5) →to Q8)

6) No idea. ☐

Q8 This is asking about the relationship between a management level of infrastructure and an affordability of municipality budget. Please choose only one appropriate option in each of 1) to 5) and tick in the ☐ like ☑.

	Response without affordability	Response with affordability
1) Complaints from residents.	☐	☐
2) Expectation of physical accidents. (Precautionary correspondence)	☐	☐
3) Occurrence of physical accidents. (Correspondence after the accidents)	☐	☐
4) Expectation of serious injuries or death. (Precautionary correspondence)	☐	☐
5) Occurrence of serious injuries or death. (Correspondence after the accidents)	☐	☐

→to Q9

Q9. This is asking about the level of development of infrastructure within your municipality.

SQ1. Do you change the level of development within your municipality? Please choose only one appropriate option, either 1) or 2) and tick in the ☐ like ☑. If you set the same level of development but give a priority in the plan, please answer 2).

1) Changing level of development of infrastructure within your municipality. ☐ →to Q9 SQ2
2) The same level of development of infrastructure within your municipality. ☐ →to Q10

SQ2. If you differentiate the level of development of infrastructure within the municipality, how do you assess it?

Please choose all appropriate options and tick in the ☐ like ☑. In addition, please tick the most prioritized one within the ticked choices in the next ○ with ✓.

1) Present population density or cumulative condition of buildings in each area.	☐	○	→to Q10
2) Future prospects for population density and the population ageing situation in each area.	☐	○	→to Q10
3) Superior plans, such as urban development plan or social development plan.	☐	○	→to Q10
4) Strength of desire by residents or assembly members.	☐	○	→to Q10
5) Others (Specifically:)	☐	○	

III. Situation of infrastructure development and management in the context of population decline within each infrastructure type

The next section asks you about the impacts of population decline on infrastructure development and management in each type of infrastructure. Please answer the following questions according to each type.

Types	Examples	Questions
Education	Primary, secondary (junior high) schools and kindergartens, nurseries.	Q10
Public dwelling	Public dwellings.	Q11
Life-style related facilities	• Social education facilities (library, gymnasium etc.) • Social care facilities (public health centre, public hospitals, social care facilities) • Sanitation, solid waste management facilities (excluding drainage and waste water management) • Community facilities • Public parks	Q12
Water supply & waste water management	Water supply & waste water management facilities.	Q13
Transport	Terminals for ferries, aviation, new transport systems and public railway services, including public-private joint operations.	Q14
Road	Roads managed by municipalities.	Q15
Emergency and disaster services	E.g. Anti-landslide, flood control, coastal erosion prevention, anti-sand dams; that are developed or managed by municipalities.	Q16

Q10. This is asking about the impacts on <u>education facilities</u> in your municipality.

SQ1. For the past 10 years, how has the numbers of students altered? Please choose <u>only one appropriate</u> option, either 1) or 2) and tick in the ☐ like ☑.

1)	Decline in the numbers of students	☐	→to Q10 SQ2
2)	No decline in the numbers of students	☐	

SQ2. In terms of <u>education facilities,</u> have the following situations occurred in those ten years due to population decline? Please choose <u>all appropriate</u> options from 1) to 11) and tick in the ☐ like ☑.

1)	Increase in the number of vacant study rooms, merged and closed facilities owing to the decline in student numbers.	☐	→to Q10 SQ3
2)	Shortening of waiting lists for entering kindergartens and nurseries.	☐	→to Q11
3)	Decrease in the revenue from user charges, such as school lunch costs.	☐	
4)	Reduction in electricity and water bills.	☐	
5)	Decline in complaints about noise around schools and kindergartens.	☐	
6)	Increase in user charges, such as school lunch costs.	☐	
7)	Contracting out of maintenance and operational work.	☐	
8)	Decline in maintenance level (e.g. reducing the frequency of cleaning and snowploughing).	☐	
9)	Somebody injured owing to a reduction in maintenance levels.	☐	
10)	Problems related to population decline threatens continuation of municipalities.	☐	
11)	Others ( )	☐	

SQ3. For respondents to 1) in SQ2. How do you deal with vacant properties? Please choose <u>all appropriate</u> options from 1) to 9) and tick in the ☐ like ☑.

1)	Leaving vacant facilities as they are due to lack of a demolition fund.	☐	→to Q11
2)	Leaving vacant facilities as they are for reasons other than lack of a demolition fund.	☐	
3)	Downsizing vacant facilities by demolishing part of them.	☐	
4)	Converting vacant facilities.	☐	
5)	Demolition of existing vacant facilities and leaving vacant land as it is.	☐	
6)	Demolition of existing vacant facilities and converting the land to other purposes.	☐	
7)	Demolition of existing vacant facilities and selling the land to private owners.	☐	
8)	Now considering future plans for the vacant properties.	☐	
9)	Others ( )	☐	

SQ4. If you have answered any of 5) to 7), please tell us the demolition cost. ______Yen/m²

Q11. This is asking about the impacts on public dwellings in your municipality.

SQ1. Do you own and manage public dwellings? Please choose only one appropriate option, either 1) or 2) and tick in the ☐ like ☑.

1)	Yes	☐	→to Q11 SQ2
2)	No	☐	→to Q12

SQ2. Do you intentionally allow a part of public dwellings to be vacant for the purpose of rebuilding or demolition? Please choose only one appropriate option, either 1) or 2) and tick the ☐ like ☑.

1)	Yes	☐	→to Q11 SQ3
2)	No	☐	

SQ3. In terms of public dwellings, have the following situations occurred in the past ten years due to population decline? Please choose all appropriate options from 1) to 11) and tick in the ☐ like ☑.

1)	Reduction in the number of houses and flats; mergers and abolition of public dwelling owing to an increase in vacant houses and rooms.	☐	→to Q11 SQ4
2)	Deterioration of safety owing to an increase in vacant public dwellings.	☐	→to Q12
3)	Deterioration of landscape owing to an increase in vacant public dwellings.	☐	
4)	Shortening of waiting lists for public dwellings.	☐	
5)	Decline in the revenue from house rents.	☐	
6)	Increase in the user burden, such as rents.	☐	
7)	Contracting out of maintenance and operational work.	☐	
8)	Increase in the user burden, such as cleaning and snow-ploughing.	☐	
9)	Decline in maintenance level (e.g. reducing the frequency of cleaning and snowploughing).	☐	
10)	Somebody injured owing to decline in maintenance levels.	☐	
11)	Problems related to population decline threaten continuation of municipalities.	☐	
12)	Others ( )	☐	

SQ4. For respondents to 1) in SQ3. How do you deal with vacant properties? Please choose all appropriate options from 1) to 9) and tick in the ☐ like ☑.

1)	Leaving vacant facilities as they are due to lack of a demolition fund.	☐	→to Q12
2)	Leaving vacant facilities as they are for reasons other than a lack of a demolition fund.	☐	
3)	Downsizing vacant facilities by demolishing a part of them.	☐	
4)	Converting vacant facilities.	☐	
5)	Demolition of existing vacant facilities and leaving vacant land as it is.	☐	
6)	Demolition of existing vacant facilities and converting the land to other purposes.	☐	
7)	Demolition of existing vacant facilities and selling the land to private owners.	☐	
8)	Now considering future plans for the vacant properties.	☐	
9)	Others ( )	☐	

SQ5. If you have answered any of 5) to 7), please tell us the demolition cost. ____Yen/m²

Q12. This is asking about impacts on Life-style related facilities in your municipality.

SQ1. Do you own and manage quality of life-related facilities? Please choose all appropriate options from 1) to 5) and tick the ☐ like ☑.

1)	Social education facilities (library, gymnasium etc.).	☐	If you do not have any of these facilities, please go to Q13, in other cases, please move on to Q12 SQ2.
2)	Social care facilities (public health centre, public hospitals, social care facilities).	☐	
3)	Sanitation, solid waste management facilities (excluding drainage and waste water management).	☐	
4)	Community facilities.	☐	
5)	Public parks.	☐	

SQ2. In terms of quality of life-related facilities, have the following situations occurred in the past ten years due to population decline? Please choose all appropriate options from 1) to 13) and tick in the ☐ like ☑.

1)	Reduction of equipment/ mergers and abandonment of facilities.	☐	→to Q12 SQ3
2)	Decline in the number of users.	☐	→to Q13
3)	Mitigating congestion in usage, and shortening waiting times.	☐	
4)	Decline in revenue from user charges.	☐	
5)	Reduction in electricity and water bills due to decline in the number of users.	☐	
6)	Reduction in complaints for noise due to reducing usage of facilities facility.	☐	
7)	Contracting out of maintenance and operational work.	☐	
8)	Increase in the user burden, such as cleaning and snow-ploughing.	☐	
9)	Increase in user charges and creation of a user burden system.	☐	
10)	Decline in maintenance level (e.g. reducing the frequency of cleaning and snowploughing).	☐	
11)	Somebody injured owing to a decline in maintenance levels	☐	
12)	Problems related to population decline threatens continuation of municipalities.	☐	
13)	Others ( )	☐	

SQ3. For respondents to 1) in SQ2. How do you deal with vacant properties? Please choose all appropriate options from 1) to 8) and tick in the ☐ like ☑.

1)	Leaving vacant facilities as they are due to lack of a demolition fund.	☐	→to Q13
2)	Leaving vacant facilities as they are for reasons other than lack of a demolition fund	☐	
3)	Downsizing vacant facilities by demolishing part of them.	☐	
4)	Converting vacant facilities.	☐	
5)	Demolition of existing vacant facilities and leaving vacant land as it is.	☐	
6)	Demolition of existing vacant facilities and converting the land to other purposes.	☐	
7)	Demolition of existing vacant facilities and selling the land to private owners.	☐	

8) Now considering future plans for the vacant properties ☐
9) Others ( ) ☐

SQ4. If you have answered any of 5) to 7), please tell us the demolition cost. _______ Yen/m²

Q13. This is asking about impacts on water supply and waste water management facilities in your municipality.

SQ1. This is asking about the development of waste water management facilities. Please answer when the waste water facilities were introduced, if you have already introduced it, in the following blank box. If not, please write "×" in the blank box.

SQ2. In terms of water supply and waste water management, have the following situations occurred in the past ten years due to population decline? Please choose all appropriate options from 1) to 13) and tick in the ☐ like ☑.

1) Mergers, abolition and reorganisation of facilities and networks. ☐ →to Q13 SQ3
2) Deteriorating water quality owing to prolonged presence of water in the pipes. ☐
3) Reduction in revenue from user fees. ☐
4) Decrease in the amount of water consumption. ☐
5) Odour occurring due to slowing down of waste water flow in the pipes. ☐
6) Worsening distribution efficiency in abandoned factory areas and regionally depopulated areas. ☐
7) Accelerated deterioration of waste water pipes due to slowing down of waste water flow. ☐ →to Q14
8) Down-grading from waste water facilities to simple septic tank system. ☐
9) Increase in the level of user charge. ☐
10) Contracting out of maintenance and operational work. ☐
11) Rescheduling of repayments of debts. ☐
12) Problems related to population decline threatening the continuation of municipalities.
13) Others ( ) ☐

SQ3. For respondents to 1) in SQ2. How do you deal with vacant properties? Please choose all appropriate options from 1) to 9) and tick in the ☐ like ☑.

1) Leaving vacant facilities as they are due to lack of a demolition fund. ☐
2) Leaving vacant facilities as they are for reasons other than lack of a demolition fund. ☐
3) Downsizing vacant facilities by demolishing part of them. ☐
4) Converting vacant facilities. ☐ →to Q14
5) Demolition of existing vacant facilities and leaving vacant land as it is. ☐
6) Demolition of existing vacant facilities and converting the land to other purposes. ☐
7) Demolition of existing vacant facilities and selling the land to private owners. ☐
8) Now considering future plans for the vacant properties. ☐

9) Others ( ) □

SQ4. If you have answered any of 5) to 7), please tell us the demolition cost. ______ Yen/m^2

Q14. This is asking for impacts on transport facilities (terminals for ferries, buses, and urban transit) in your municipality.

SQ1. Do you own and manage transport facilities? Please choose only one appropriate option, either 1) or 2) and tick in the ☐ like ☑.

1)	Yes	☐	→to Q14 SQ2
2)	No	☐	→to Q15

SQ2. In terms of transport facilities, have the following situations occurred in the past ten years due to population decline? Please choose all appropriate options from 1) to 12) and tick in the ☐ like ☑.

1)	Occurrence of closed, merged and abolished facilities.	☐	→to Q14 SQ3
2)	Decline in numbers of users.	☐	→to Q15
3)	Declining or abolished transport services.	☐	→to Q15
4)	Decline in the revenue from user charges.	☐	→to Q15
5)	Decline in electricity and water bills for management and operation.	☐	→to Q15
6)	Decline in complaints for noise and emission of gases.	☐	→to Q15
7)	Increase in user charges.	☐	→to Q15
8)	Contracting out of maintenance and operational work.	☐	→to Q15
9)	Decline in maintenance level (e.g. reducing the frequency of cleaning and snowploughing).	☐	→to Q15
10)	Somebody injured owing to a decline in maintenance levels.	☐	→to Q15
11)	Problems related to population decline threatens continuation of municipalities.	☐	→to Q15
12)	Others ( )	☐	→to Q15

SQ3. For respondents to 1) in SQ2. How do you deal with vacant properties? Please choose all appropriate options from 1) to 9) and tick in the ☐ like ☑.

1)	Leaving vacant facilities as they are due to lack of a demolition fund.	☐	→to Q15
2)	Leaving vacant facilities as they are for reasons other than lack of a demolition fund.	☐	→to Q15
3)	Downsizing vacant facilities by demolishing part of them.	☐	→to Q15
4)	Converting vacant facilities.	☐	→to Q15
5)	Demolition of existing vacant facilities and leaving vacant land as it is.	☐	→to Q15
6)	Demolition of existing vacant facilities and converting the land to other purposes.	☐	→to Q15
7)	Demolition of existing vacant facilities and selling the land to private owners.	☐	→to Q15
8)	Now considering future plans for the vacant properties.	☐	→to Q15
9)	Others ( )	☐	

SQ4. If you have answered any of 5) to 7), please tell us the demolition cost. _______Yen/m²

Q15. This is asking about the impacts on streets in your municipality.

SQ1. In terms of streets, have the following situations occurred in the past ten years due to population decline? Please choose all appropriate options from 1) to 12) and tick in the ☐ like ☑.

1)	Abolition of streets in areas where there is no longer a population.	☐	→to Q15 SQ2
2)	Occurrence of almost traffic-free streets.	☐	→to Q16
3)	Reduction in traffic accidents due to decline in traffic.	☐	
4)	Mitigation of congestion due to decline in traffic.	☐	
5)	Decline in tax revenues owing to decline in sales volume of automobiles and motor-bikes.	☐	
6)	Reduction in pollution, such as noise, vibration and air pollution due to decline in traffic.	☐	
7)	Contracting out of maintenance and operational work.	☐	
8)	Increase in the user burden, such as cleaning and snow-ploughing.	☐	
9)	Decline in maintenance levels (e.g. reducing the frequency of cleaning and snowploughing).	☐	
10)	Somebody injured owing to a decline in maintenance levels	☐	
11)	Problems related to population decline threatens continuation of municipalities.	☐	
12)	Others ( )	☐	

SQ2. For respondents to 1) in SQ1. How do you deal with vacant properties? Please choose all appropriate options from 1) to 9) and tick in the ☐ like ☑.

1)	Leaving streets closed as they are due to lack of a demolition fund.	☐	→to Q16
2)	Leaving streets closed as they are for reasons other than lack of a demolition fund.	☐	
3)	Downsizing streets by reducing the number of traffic lanes.	☐	
4)	Demolition of existing street beds and pavements and leaving vacant land as it is.	☐	
5)	Demolition of existing street beds and pavements and leaving vacant land as it is after environmental restoration.	☐	
6)	Demolition of existing street beds and pavements and converting the land to other purposes.	☐	
7)	Demolition of existing street beds and pavements and selling the land to private owners.	☐	
8)	Now considering future plans for the vacant properties.	☐	
9)	Others ( )	☐	

SQ3. If you have answered any of 4) to 7), please tell us the demolition cost. _____Yen/m²

Q16. This is asking about the impacts on emergency and disaster facilities in your municipality.

SQ1. Do you own and manage emergency and disaster facilities? Please choose all appropriate options from 1) to 5) and tick in the ☐ like ☑. In addition, if you are have outsourced maintenance of those facilities to prefectures, please tick in the ○next to ☐.

1)	Anti–landslide.	☐	○	If you do not have any of these facilities, please go to Q17; otherwise please move on to Q16 SQ2.
2)	Flood control.	☐	○	
3)	Anti coastal erosion.	☐	○	
4)	Anti sand-slide dams.	☐	○	

SQ2. In terms of emergency and disaster facilities, have the following situation occurred for this ten years due to population decline? Please choose all appropriate options from 1) to 12) and tick in the ☐ like ☑.

1)	Abolition of emergency and disaster facilities.	☐	→to Q16 SQ3
2)	Decline in the number of households needing to be served.	☐	→to Q17
3)	Reduction of the fee of outsourced maintenance of emergency and disaster facilities owing to strong budgetary constraints in prefectures	☐	
4)	Postponing and suspending constructions of emergency and disaster facilities	☐	
5)	Contracting out of maintenance and operation works	☐	
6)	Increase in the user burden such as cleaning and snow-ploughing	☐	
7)	Decline in maintenance level (e.g. reducing the frequency of weeding etc.)	☐	
8)	Decline in the effect of emergency and disaster owing to decline in a maintenance level	☐	
9)	Problems related to population decline threatens continuation of municipalities.		
10)	Others ( )	☐	

SQ3. For respondents to 1) in SQ2. How do you deal with vacant properties? Please choose all appropriate options from 1) to 9) and tick in the ☐ like ☑.

1)	Leaving vacant facilities as they are due to lack of a demolition fund.	☐	→to Q17
2)	Leaving vacant facilities as they are for reasons other than lack of a demolition fund.	☐	
3)	Downsizing vacant facilities by demolishing part of them.	☐	
4)	Converting vacant facilities.	☐	
5)	Demolition of existing vacant facilities and leaving vacant land as it is.	☐	
6)	Demolition of existing vacant facilities and converting the land to other purposes.	☐	
7)	Demolition of existing vacant facilities and selling the land to private owners.	☐	
8)	Now considering future plans for the vacant properties	☐	
9)	Others ( )	☐	

SQ4. If you have answered any of 5) to 7), please tell us the demolition cost. _______Yen/m²

IV. Problems and counter-policies for population decline

Q17～19 are asking about new policies to mitigate various problems of population decline. Please answer them frankly.

Q17. This is asking about problems accompanying increases in the number of vacant properties, and mitigation policies for them.

SQ1. Are you experiencing the following situations? If you have either already experienced the situation, or you can assume that it is highly likely to occur, please tick in the right-hand side □ like☑.

In addition, have you considered how to respond to these occurrences? If so, please tick in the ○ next to □ with✓.

	Occurrence	Problem	
1) The number of vacant properties is increasing and causes some nuisances to surroundings.	□	○	To Q17 SQ2
2) Hard to urge tax payments and response to complaints from absent landlords.	□	○	
3) Increasing burdens of urging and collecting tax on vacant properties from absent landlords	□	○	

SQ2. To solve the situation answered in SQ1, can you regard the following Policies A to C as effective? Please choose one box in each line (each policy) and tick in the □ like ☑.

Policy A: Increasing the rate of the property tax on vacant properties.
Policy B: Municipale support for disposal of vacant properties, such as matching between vendors and vendees.
Policy C: Introducing a citizen number system and the levying of all taxes simultaneously. In addition, if there is non-payment, the resident municipality has a responsibility to collect it and pay the same amount of tax revenue to other related municipalities regardless of collection.

	Effective	Effective if introduced simultaneously with the other two policies	Effective, but hard to introduce it	Ineffective	No idea	
Policy A :	□	□	□	□	□	To Q17 SQ3.
Policy B :	□	□	□	□	□	
Policy C :	□	□	□	□	□	

SQ3. Please write here any ideas that you have additional to the above-mentioned policies in SQ2 for solving the situation assumed in SQ1.

Q18. This is asking about the problems and mitigation policy on urban development and redevelopment in the context of population decline.

SQ1. Have you experienced the following situations? If you have either already experienced the situation, or you can assume that it is highly likely to occur, please tick in the right-hand side ☐ like☑.

In addition, have you considered how to respond to these occurrences? If so, please tick in the ○ next to ☐ with✓.

	Occurrence	Problems	
1) A municipality has to develop new infrastructure itself for redevelopment of abandoned factories or, for instance, a new development of a huge shopping mall.	☐	○	To Q18 SQ2
2) Agricultural fields have often been developed because brownfield sites with vacant properties have not redeveloped smoothly.	☐	○	
3) Development benefits are not returned to the region by developers.	☐	○	

SQ2. To solve the situation answered in SQ1, can you regard the following Policies A to D as effective? Please choose one box in each line (each policy) and tick in the ☐ like ☑.

Policy A. Developing a new policy for developers to have to return some of development benefits to the region directly.
Policy B. Creating an urban development plan that reflects existing infrastructures and rejecting development plans because of existing infrastructure capacities.
Policy C. Imposing an overcharge on developers in case a municipality has to develop new infrastructures in connection with a new development.
Policy D. Requiring demolition costs to be placed in an escrow account as a precaution against either developers or property owners leaving dangerous vacant facilities abandoned.

	Effective	Effective if introduced simultaneously with the other three policies	Effective, but hard to introduce it	Ineffective	No idea	
Policy A :	☐	☐	☐	☐	☐	To Q18 SQ3
Policy B :	☐	☐	☐	☐	☐	
Policy C :	☐	☐	☐	☐	☐	
Policy D :	☐	☐	☐	☐	☐	

SQ3. Please write here any ideas that you have additional to the above-mentioned policies in SQ2 for solving the situation assumed in SQ1.

Q19. This is asking about the problems and policy solutions caused by infrastructure development for industries in the context of population decline.

SQ1. Have you experienced the following situations? If you have either already experienced the situation, or you can assume that it is highly likely to occur, please tick in the right-hand side ☐ like☑.

In addition, have you considered how to respond to these occurrences? If so, please tick in the ○ next to ☐ with✓.

		Occurrence	Problems	
1)	Previous expenditures for industrial infrastructure development have been a main cause of fiscal constraints.	☐	○	
2)	The operating ratio of industrial infrastructures has become underperforming owing to duplication within neighbourhoods.	☐	○	To Q19 SQ2
3)	The operating ratio of industrial infrastructures has become underperforming owing to an excess demand projection.	☐	○	

SQ2. To solve the situation answered in SQ1, can you regard the following Policies A to D as effective? Please choose <u>one</u> box in <u>each line</u> (each policy) and tick in the ☐ like ☑.

Policy A. Uniting the authorities of investing and lending for industrial infrastructure development from municipalities to prefectures.

Policy B. Each municipality cooperates with private companies to create a development plan for industrial infrastructure, and competes with other regions to obtain subsidies for the development from a prefecture.

Policy C. A condition for public investment or lending is at least a balancing of investment and return before public finance support is provided.

Policy D. Municipalities and prefectures should disclose the period for obtaining a financial return, with consideration of related tax revenue, such as property taxes.

	Effective	Effective if introduced simultaneously with the other three policies	Effective, but hard to introduce it	Ineffectiv e	No idea	
Policy A :	☐	☐	☐	☐	☐	
Policy B :	☐	☐	☐	☐	☐	To Q19 SQ3
Policy C :	☐	☐	☐	☐	☐	
Policy D :	☐	☐	☐	☐	☐	

SQ3. Please write here any ideas that you have additional to the above-mentioned policies in SQ2 for solving the situation assumed in SQ1.

V. Others

Q20. For how many years do you have the following fiscal materials with regard to general municipality accounts, special purpose accounts, and public enterprise accounts?

- Maintenance costs for each governmental purpose (Table 20)
- Investments: general construction works (Table 21, 22, 23)
- Investment: land acquisition costs (Table 71,72,73)

→to Q21

____________________years

Q21. Please write additional comments on any topic in the blank box below.

This is the end of the questionnaire.
Thank you for your cooperation.

QUESTIONNAIRE FOR USERS

The original version of the questionnaire was computer-aided web survey in Japanese. The following is the English translation of it. This survey was jointly conducted with Nomura Research Institute, the University of Tokyo, and the Kansai University granted by Nomura Research Institute, which the author works for. The survey was originally designed for this thesis by the author but the co-researchers can also use the results of the survey.

Purpose and scope of the survey

Background

Since 2006, Japan's population has been declining. The depopulated society could no more allow positive investments in infrastructure so far. In addition, supposing population decline, all of existing infrastructures will not be able to be maintained appropriately. Nonetheless, there are not enough arguments on the balance between the level of infrastructure provisions and expected increases in the maintenance costs of infrastructures in Japan at present.

Scope

This questionnaire asks respondents some questions in terms of the feelings on the impacts of population decline on infrastructures. Secondly, this questionnaire also asks the balance between future increases in the user financial burden and infrastructure provision especially on the public facilities supporting ordinary lives of people, water supply and road.

Purpose

This questionnaire aims both to clarify the present ideas by general people and to discuss the balance between future increases in the user financial burden and infrastructure provisions. The result of this questionnaire will be manipulated by statistics methods and will be used in the academic research and policy proposals by London School of Economics and Political Science, the University of Tokyo, Kansai University and Nomura Research Institute. Accordingly, there is no possibility to open the personal information to the public.

Objective infrastructure

Types	Examples
Education	Primary, secondary (junior high) schools and kindergartens, nurseries.
Life-style related facilities	Social education facilities (library, gymnasium etc.) Social care facilities (public health centre, public hospitals, social care facilities) Sanitation, solid waste management facilities (excluding drainage and waste water management) Community facilities Public parks
Water supply & waste water management	Water supply & waste water management facilities.
Emergency and disaster services	E.g. Anti-landslide, flood control, coastal erosion prevention, anti-sand dams; that are developed or managed by municipalities.

Notice

In some questions, we will ask your water charge and the monthly payment to buy gasoline and diesels for your self-use automobiles. If necessary, please prepare some materials e.g. receipt and so on, to answer those questions. The numbers in those questions are not necessarily accurate but are expected to be estimated and answered.

Usage & Experience

Here, we ask the situation of usage and experience in terms of infrastructures. Please answer them with following instruction.

Please answer the following sub questions.

Public facilities which you use in ordinary life. (SA). If you use multiple facilities within the same category, for instance, a gymnasium and a baseball park, please answer it with assuming the most frequent using facilities.
In terms of the answered choice, please answer the ordinary transportation to the facilities and also answer the time to destination.
When you pay the fee for using the answered facilities, please answer the fee per one usage

Type of public facilities	Transport	Time	Fee
Library	Walking Bicycle Automobile Bus Taxi Railway, metro, LRT Others ( )	minutes	Yen/usage
Community facilities	Walking Bicycle Automobile Bus Taxi Railway, metro, LRT Others ( )	minutes	Yen/usage
Gymnasium, athletic facilities and so on	Walking Bicycle Automobile Bus Taxi Railway, metro, LRT Others ( )	minutes	Yen/usage
Social care facilities	Walking Bicycle Automobile Bus Taxi Railway, metro, LRT Others ( )	minutes	Yen/usage

Urban park	Walking Bicycle Automobile Bus Taxi Railway, metro, LRT Others ( )	minutes	Yen/usage
City hall	Walking Bicycle Automobile Bus Taxi Railway, metro, LRT Others ( )	minutes	Yen/usage
Other public facilities e.g. ________________	Walking Bicycle Automobile Bus Taxi Railway, metro, LRT Others ( )	minutes	Yen/usage
I don't use any public facilities in my ordinal life			

Asking this question to those who answered 1) to 7) in the previous question. Which public facility do you use the most often from 1) to 7)? (SA) ____________

Please answer the type of waste water management service used in your house from the following choices. (SA)

- Earth Closet
- Simple septic tank
- Public waste water management
- Other (   )
- Not sure

Are there the following anti-disaster facilities around you? Please answer the situation in each type.

Types of anti-disaster	Existence around you
1) Levee of rivers	Yes No
2) Anti-landslide wall	Yes No
3) Levee at the coast	Yes No
4) Sand-trap dams	Yes No

Did you or others that you know of experience any of injuries below?

1) Injuries or accidents at education facilities due to insufficient management by the government	No	Yes
3) Injuries or accidents at public facilities due to insufficient management by the government	No	Yes
4) Injuries or accidents at water supply and waste water management facilities due to insufficient management by the government	No	Yes
7) Injuries or accidents at anti-disaster facilities due to insufficient management by the government	No	Yes

Awareness

Overall

How do you think that population has changed in your area in the last 15 years? Please select one choice from them. If you have not lived there for 15 years, please answer as long as you can know it.

Declined a lot	Declined a little	Stable	Increased a little	Increased a lot	Not sure
□	□	□	□	□	□

Are you aware of any vacant infrastructures around you? If you know it, please answer "Yes" in each infrastructure type. If not, please answer "No".

1) abolished education facilities	Yes	No
3) abolished Library, gymnasium, social care facilities, urban park etc.	Yes	No
4) abolished Pipes, pumps and filtering facilities etc.	Yes	No
7) abolished levee or sand trap dams	Yes	No

The following section is for only those who answered 'yes' in the above questions in each infrastructure type. Do confirm whether it is possible to show up the following questions in accordance with the previous answer situation.

Environment

Some people think that vacant facilities will spoil a landscape. For the other people, this is not concern. Then, how do you consider the visual impacts of vacant facilities on landscape? Please answer it in each infrastructure type.

How is the landscape affected by the present of vacant education facilities?

Much better	A little better	Not change	A little worse	Much worse	Not sure
□	□	□	□	□	□

How is the landscape affected by the present of vacant library, gymnasium, social care facilities, urban park etc?

Much better	A little better	Not change	A little worse	Much worse	Not sure
□	□	□	□	□	□

How is the landscape affected by the present of vacant pipes, pumps and filtering facilities etc.?

Much better	A little better	Not change	A little worse	Much worse	Not sure
□	□	□	□	□	□

How is the landscape affected by the present of abandoned levee or sand trap dams?

Much better	A little better	Not change	A little worse	Much worse	Not sure
□	□	□	□	□	□

Society

How do you notice in the following situation of infrastructures provided by municipalities compared with the last 15 years? If you have not lived there for 15 years, please answer as long as you can know it.

time and distance to education facilities

Much better	A little better	No change	A little worse	Much worse	Not sure
□	□	□	□	□	□

number of and time and distance for the public facilities such as library, gymnasium, social care facilities

Much better	A little better	No change	A little worse	Much worse	Not sure
□	□	□	□	□	□

water quality

Much better	A little better	No change	A little worse	Much worse	Not sure
□	□	□	□	□	□

development situation of levee and land slide preventions

Much better	A little better	No change	A little worse	Much worse	Not sure
□	□	□	□	□	□

Some people think that vacant facilities will spoil a safety in the area. For the other people, this is not concern. Then, how do you consider the impacts of vacant facilities on safety in your living area? Please answer it in each infrastructure type.

How is the safety affected by the present of vacant education facilities?

Much better	A little better	No change	A little worse	Much worse	Not sure
□	□	□	□	□	□

How is the safety affected by the present of vacant library, gymnasium, social care facilities, urban park etc?

Much better	A little better	No change	A little worse	Much worse	Not sure
□	□	□	□	□	□

How is the safety affected by the present of vacant pipes, pumps and filtering facilities etc.?

Much better	A little better	No change	A little worse	Much worse	Not sure
□	□	□	□	□	□

How is the safety affected by the present of vacant levee or sand trap dams?

Much better	A little better	No change	A little worse	Much worse	Not sure
□	□	□	□	□	□

Engineering

How do you feel the maintenance level of the following infrastructures changed for the last 15 years? If you have not lived there for 15 years, please answer as long as you can know it. If you don’t use the following infrastructure recently, please answer “not sure”.

education facilities

Much better	A little better	No change	A little worse	Much worse	Not sure
□	□	□	□	□	□

Library, gymnasium, social care facilities, urban park etc?

Much better	A little better	No change	A little worse	Much worse	Not sure
□	□	□	□	□	□

Pipes, pumps and filtering facilities etc.?

Much better	A little better	No change	A little worse	Much worse	Not sure
□	□	□	□	□	□

Levee or sand trap dams?

Much better	A little better	No change	A little worse	Much worse	Not sure
□	□	□	□	□	□

Economy

Have the following user charges to use infrastructures increased in your municipality for the last 15 years? If you have not lived there for 15 years, please answer as long as you can know it.

Tuition and school lunch fee in compulsory education and nursery

Large increase	Small increase	No change	Small decrease	Large decrease	Not sure
□	□	□	□	□	□

User charge for using gymnasium, social care facilities and so on

Large increase	Small increase	No change	Small decrease	Large decrease	Not sure
□	□	□	□	□	□

User charge on water supply and waste water management

Large increase	Small increase	No change	Small decrease	Large decrease	Not sure
□	□	□	□	□	□

User financial burden for preparing the stocks in the disaster management warehouse in the community

Large increase	Small increase	No change	Small decrease	Large decrease	Not sure
□	□	□	□	□	□

Overall again

Demolition of abandoned infrastructures also needs financial resources. Do you consider the abandoned infrastructure should be demolished as soon as possible even if tax rate or user charge will be increased? Please answer it in each infrastructure type.

1) abolished education facilities	No	Yes
3) abolished Library, gymnasium, social care facilities, urban park etc.	No	Yes
4) abolished Pipes, pumps and filtering facilities etc.	No	Yes
7) abolished levee or sand trap dams	No	Yes

Attitude

In this question, we will present of series of situation regarding infrastructure change. For each situation, please consider whether you would consider moving away from your living area because of infrastructure situation.

	To consider moving		
1) In case of deteriorating the engineering safety and convenience of education facilities	May be No	May be Yes	Not sure
2) In case of deteriorating the engineering safety and convenience of public facilities such as library, gymnasium, and social care facilities and so on and increasing the risk of accidents	May be No	May be Yes	Not sure
3) In case of abolishing those public facilities and resulting in the worsening convenience to use them	May be No	May be Yes	Not sure
4) In case of deteriorating the engineering safety and consequently bursting water supply pipes and suspending water supply	May be No	May be Yes	Not sure
5) In case of increasing in user charge twice as much as the current level for water supply	May be No	May be Yes	Not sure
6) In case of increasing in the risk of disaster occurrence due to insufficient anti-disaster infrastructure management	May be No	May be Yes	Not sure

Choice modelling

Public facilities[14]

Possibility of infrastructure development and management in depopulated society

Because of population decline, in order to maintain current condition, service and amount of infrastructure, user charges are likely to double ***in the future.***

However, there are other possibilities. The municipality can let the condition, service and amount of infrastructure deteriorate which would reduce the future financial burden to the public.

Alternatively, the municipalities could invest future in infrastructures improvement which would lead to even higher financial burden.

The following questions will ask you the level of ***PUBLIC FACILITIE's (reflecting the answer in QA2)*** development and maintenance in the future in six times. Every time, three choices will be presented and please choose the most favour one.

Attributes	← Level →		Status Quo		
Assumed Year	2100	2055	2040	2025	2010
Acceccibility (time distance to the ***Life-style supported facilities QA1***)	Time-distance will become twice _____(***2*QA1) as much***)	Time-distance will become 1.5 times _____(***1.5*QA1) as much***	Time-distance will become **the same** _____(***QA1) as much***	Time-distance will become 0.5 times _____(0***.5*QA1) as much***	
Safety	Annually 5 persons will get injured	Annually 1 persons will get injured	Annually 0.2 persons will get injured	Annually 0.04 persons will get injured	
Environemnt		Deteriorating the outward appearance owing to insufficiently cleaning outside wall and not caring plants in the future	Keep the present situation even in the future	Improving the outward appearance due to cleaning outside wall and gardening even in the future	
Economy	Potential cost of using facilities will decline from present monthly ***1000 yen (QA1)*** to the **half**, monthly ***500 (0.5*QA1) yen,*** as much and result in the decline in user fee or local taxes	Potential cost of using facilities will be the same, monthly ***1000 yen (QA1)*** as much as that of the present	Potential cost of using facilities will increase from present monthly ***1000 yen (QA1)*** to **twice**, monthly ***2000(2*QA1) yen,*** as much and result in the increase in user fee or local taxes	Potential cost of using facilities will increase from present monthly ***1000 yen (QA1)*** to **four times**, monthly ***4000(4*QA1) yen,*** as much and result in the increase in user fee or local taxes	Potential cost of using facilities will increase from present monthly ***1000 yen (QA1)*** to **eight times**, monthly ***8000(8*QA1) yen,*** as much and result in the increase in user fee or local taxes

Please choose the most favour one and check in the bottom box

	Choice 1	Choice 2	Choice 3
Assumed Year	2040	2100	2025
Accessibility (Society)	Time-distance will become the same _____(QA1) as much	Time-distance will become the same _____(QA1) as much	Time-distance will become the same _____(QA1) as much
Engineering Safety	Annually 0.2 persons will get injured	Annually 0.2 persons will get injured	Annually 0.04 persons will get injured
Environment	Keep the present situation even in the future	Improving the outward appearance due to cleaning outside wall and gardening even in the future	Keep the present situation even in the future
Economy	Potential cost of using facilities will increase from present monthly 1000 yen (QA1) to twice, monthly 2000(2*QA1) yen, as much and result in the increase in user fee or local taxes	Potential cost of using facilities will be the same, monthly 1000 yen (QA1) as much as that of the present	Potential cost of using facilities will increase from present monthly 1000 yen (QA1) to four times, monthly 4000(4*QA1) yen, as much and result in the increase in user fee or local taxes
	☐	☐	☐

[14] Reminder

Note1: to reflect the kind of life-style support facilities, time-distance, fee in terms of the best-use facilities in QA2

Note2: in case the respondent answered 8) in QA1 or no-fee is required for using the facilities answered in QA2, the following data will be used

A kind of public facilities: just write as "public facilities"

Time-distance" 10 minutes on feet

Fee or tax: ______ now estimating

Please choose the most favour one and check in the bottom box

	Choice 1	Choice 2	Choice 3
Assumed Year	2040	2025	2010
Accessibility (Society)	Time-distance will become the same _____(QA1) as much	Time-distance will become 1.5 times _____(1.5*QA1) as much	Time-distance will become 0.5 times _____(0.5*QA1) as much
Engineering Safety	Annually 0.2 persons will get injured	Annually 0.2 persons will get injured	Annually 1 persons will get injured
Environment	Keep the present situation even in the future	Improving the outward appearance due to cleaning outside wall and gardening even in the future	Improving the outward appearance due to cleaning outside wall and gardening even in the future
Economy	Potential cost of using facilities will increase from present monthly 1000 yen (QA1) to twice, monthly 2000(2*QA1) yen, as much and result in the increase in user fee or local taxes	Potential cost of using facilities will decline from present monthly 1000 yen (QA1) to the half, monthly 500 (0.5*QA1) yen, as much and result in the decline in user fee or local taxes	Potential cost of using facilities will increase from present monthly 1000 yen (QA1) to eight times, monthly 8000(8*QA1) yen, as much and result in the increase in user fee or local taxes
	☐	☐	☐

Please choose the most favour one and check in the bottom box

	Choice 1	Choice 2	Choice 3
Assumed Year	2040	2055	2040
Accessibility (Society)	Time-distance will become the same _____(QA1) as much	Time-distance will become 0.5 times _____(0.5*QA1) as much	Time-distance will become the same _____(QA1) as much
Engineering Safety	Annually 0.2 persons will get injured	Annually 0.04 persons will get injured	Annually 1 persons will get injured
Environment	Keep the present situation even in the future	Improving the outward appearance due to cleaning outside wall and gardening even in the future	Deteriorating the outward appearance owing to insufficiently cleaning outside wall and not caring plants in the future
Economy	Potential cost of using facilities will increase from present monthly 1000 yen (QA1) to twice, monthly 2000(2*QA1) yen, as much and result in the increase in user fee or local taxes	Potential cost of using facilities will decline from present monthly 1000 yen (QA1) to the half, monthly 500 (0.5*QA1) yen, as much and result in the decline in user fee or local taxes	Potential cost of using facilities will be the same, monthly 1000 yen (QA1) as much as that of the present
	☐	☐	☐

Please choose the most favour one and check in the bottom box

	Choice 1	Choice 2	Choice 3
Assumed Year	2040	2100	2010
Accessibility (Society)	Time-distance will become the same _____(QA1) as much	Time-distance will become 0.5 times _____(0.5*QA1) as much	Time-distance will become twice _____(2*QA1) as much
Engineering Safety	Annually 0.2 persons will get injured	Annually 5 persons will get injured	Annually 5 persons will get injured
Environment	Keep the present situation even in the future	Keep the present situation even in the future	Deteriorating the outward appearance owing to insufficiently cleaning outside wall and not caring plants in the future
Economy	Potential cost of using facilities will increase from present monthly 1000 yen (QA1) to twice, monthly 2000(2*QA1) yen, as much and result in the increase in user fee or local taxes	Potential cost of using facilities will increase from present monthly 1000 yen (QA1) to twice, monthly 2000(2*QA1) yen, as much and result in the increase in user fee or local taxes	Potential cost of using facilities will increase from present monthly 1000 yen (QA1) to four times, monthly 4000(4*QA1) yen, as much and result in the increase in user fee or local taxes
	☐	☐	☐

Please choose the most favour one and check in the bottom box

	Choice 1	Choice 2	Choice 3
Assumed Year	2040	2025	2100
Accessibility (Society)	Time-distance will become the same _____(QA1) as much	Time-distance will become 0.5 times _____(0.5*QA1) as much	Time-distance will become 1.5 times _____(1.5*QA1) as much
Engineering Safety	Annually 0.2 persons will get injured	Annually 0.2 persons will get injured	Annually 5 persons will get injured
Environment	Keep the present situation even in the future	Deteriorating the outward appearance owing to insufficiently cleaning outside wall and not caring plants in the future	Improving the outward appearance due to cleaning outside wall and gardening even in the future
Economy	Potential cost of using facilities will increase from present monthly 1000 yen (QA1) to twice, monthly 2000(2*QA1) yen, as much and result in the increase in user fee or local taxes	Potential cost of using facilities will be the same, monthly 1000 yen (QA1) as much as that of the present	Potential cost of using facilities will be the same, monthly 1000 yen (QA1) as much as that of the present
	☐	☐	☐

Please choose the most favour one and check in the bottom box

	Choice 1	Choice 2	Choice 3
Assumed Year	2040	2010	2010
Accessibility (Society)	Time-distance will become the same _____(QA1) as much	Time-distance will become twice _____(2*QA1) as much	Time-distance will become 1.5 times _____(1.5*QA1) as much
Engineering Safety	Annually 0.2 persons will get injured	Annually 0.2 persons will get injured	Annually 0.04 persons will get injured
Environment	Keep the present situation even in the future	Keep the present situation even in the future	Deteriorating the outward appearance owing to insufficiently cleaning outside wall and not caring plants in the future
Economy	Potential cost of using facilities will increase from present monthly 1000 yen (QA1) to twice, monthly 2000(2*QA1) yen, as much and result in the increase in user fee or local taxes	Potential cost of using facilities will be the same, monthly 1000 yen (QA1) as much as that of the present	Potential cost of using facilities will be the same, monthly 1000 yen (QA1) as much as that of the present
	☐	☐	☐

Do you think that you can understand the meaning of the instruction and sentences of this question?

- Yes
- No

Water

. How much do you pay the water charge monthly? Please answer estimation and if you pay every two month, please write down it in the right hand side space. In case you pay sanitation charge, you also add such amount in the answer.

___________yen/ ___months

Possibility of infrastructure development and management in depopulated society

Because of population decline, in order to maintain current condition, service and amount of infrastructure, user charges are likely to double ***in the future.***

However, there are other possibilities.The municipality can let the condition, service and amount of infrastructure deteriorate which would reduce the future financial burden to the public.

Alternatively, the municipalities could invest future in infrastructures improvement which would lead to even higher financial burden.

The following questions will ask you the level of ***WATER and WASTE WATER FACILITIE's*** development and maintenance in the future in six times. Every time, three choices will be presented and please choose the most favour one.

Attributes	← Level →		Status Quo		
Assumed Year	2100	2055	2040	2025	2010
Water quality		Not satisfying with the regulation for drinking, but no problem on the usage of cooking, washing and so on.	Satisfying with the regulation for drinking, but sombody minds its smell and taste.	Satisfying with the regulation for drinking and no complaints on the taste and smell of water	
Safety	Daily 20 accidents of leaking water, which is 5 times as much, from the water supply or waste water drainage pipes in one prefecture	Daily 10 accidents of leaking water, which is 2.5 times as much, from the water supply or waste water drainage pipes in one prefecture	Daily 4 accidents of leaking water, which is the same as the present situation, from the water supply or waste water drainage pipes in one prefecture	The situation will be improved and there is no leaking accidents except for scheduled maintenance.	
Environemnt		Odour, soil contamination, water quality deterioration of discharged water will not be ignoable and will occur significant damage	Odour, soil contamination, water quality deterioration of discharged water will be ignorable.	The waste water management will be perfect and the problem of odour, soil contamination, water quality deterioration of discharged water will not occur at all.	
Economy	User charge will decline to monthly 500 yen (0.5*QA17) compared with the present charge monthly 1000 yen (QA 17).	User charge will keep the same level as the present charge monthly 1000 yen (QA 17).	User charge will increase upto monthly 1500 yen (1.5*QA17) compared with the present charge monthly 1000 yen (QA 17).	User charge will increase upto monthly 2000 yen (2.0*QA17) compared with the present charge monthly 1000 yen (QA 17).	User charge will increase upto monthly 2500 yen (2.5*QA17) compared with the present charge monthly 1000 yen (QA 17).

Please choose the most favour one and check in the bottom box

	Choice 1	Choice 2	Choice 3
Assumed Year	2040	2100	2025
Accessibility (Society)	Satisfying with the regulation for drinking, but sombody minds its smell and taste.	Satisfying with the regulation for drinking, but sombody minds its smell and taste.	Satisfying with the regulation for drinking, but sombody minds its smell and taste.
Engineering Safety	Daily 4 accidents of leaking water, which is the same as the present situation, from	Daily 4 accidents of leaking water, which is the same as the present situation, from	The situation will be improved and there is no leaking accidents except for scheduled
Environment	Odour, soil contamination, water quality deterioration of discharged water will be ignorable.	The waste water management will be perfect and the problem of odour, soil contamination, water quality deterioration	Odour, soil contamination, water quality deterioration of discharged water will be ignorable.
Economy	User charge will increase upto monthly 1500 yen (1.5*QA17) compared with the present charge monthly 1000 yen (QA 17).	User charge will keep the same level as the present charge monthly 1000 yen (QA 17).	User charge will increase upto monthly 2000 yen (2.0*QA17) compared with the present charge monthly 1000 yen (QA 17).
	□	□	□

Please choose the most favour one and check in the bottom box

	Choice 1	Choice 2	Choice 3
Assumed Year	2040	2025	2010
Accessibility (Society)	Satisfying with the regulation for drinking, but sombody minds its smell and taste.	Not satisfying with the regulation for drinking, but no problem on the usage of	Satisfying with the regulation for drinking and no complaints on the taste and smell
Engineering Safety	Daily 4 accidents of leaking water, which is the same as the present situation, from	Daily 4 accidents of leaking water, which is the same as the present situation, from	Daily 10 accidents of leaking water, which is 2.5 times as much, from the water
Environment	Odour, soil contamination, water quality deterioration of discharged water will be ignorable.	The waste water management will be perfect and the problem of odour, soil contamination, water quality deterioration	The waste water management will be perfect and the problem of odour, soil contamination, water quality deterioration
Economy	User charge will increase upto monthly 1500 yen (1.5*QA17) compared with the present charge monthly 1000 yen (QA 17).	User charge will decline to monthly 500 yen (0.5*QA17) compared with the present charge monthly 1000 yen (QA 17).	User charge will increase upto monthly 2500 yen (2.5*QA17) compared with the present charge monthly 1000 yen (QA 17).
	☐	☐	☐

Please choose the most favour one and check in the bottom box

	Choice 1	Choice 2	Choice 3
Assumed Year	2040	2055	2040
Accessibility (Society)	Satisfying with the regulation for drinking, but sombody minds its smell and taste.	Satisfying with the regulation for drinking and no complaints on the taste and smell	Satisfying with the regulation for drinking, but sombody minds its smell and taste.
Engineering Safety	Daily 4 accidents of leaking water, which is the same as the present situation, from	The situation will be improved and there is no leaking accidents except for scheduled	Daily 10 accidents of leaking water, which is 2.5 times as much, from the water
Environment	Odour, soil contamination, water quality deterioration of discharged water will be ignorable.	The waste water management will be perfect and the problem of odour, soil contamination, water quality deterioration	Odour, soil contamination, water quality deterioration of discharged water will not be ignoable and will occur significant
Economy	User charge will increase upto monthly 1500 yen (1.5*QA17) compared with the present charge monthly 1000 yen (QA 17).	User charge will decline to monthly 500 yen (0.5*QA17) compared with the present charge monthly 1000 yen (QA 17).	User charge will keep the same level as the present charge monthly 1000 yen (QA 17).
	☐	☐	☐

Please choose the most favour one and check in the bottom box

	Choice 1	Choice 2	Choice 3
Assumed Year	2040	2100	2010
Accessibility (Society)	Satisfying with the regulation for drinking, but sombody minds its smell and taste.	Satisfying with the regulation for drinking and no complaints on the taste and smell	0
Engineering Safety	Daily 4 accidents of leaking water, which is the same as the present situation, from	Daily 20 accidents of leaking water, which is 5 times as much, from the water supply	Daily 20 accidents of leaking water, which is 5 times as much, from the water supply
Environment	Odour, soil contamination, water quality deterioration of discharged water will be ignorable.	Odour, soil contamination, water quality deterioration of discharged water will be ignorable.	Odour, soil contamination, water quality deterioration of discharged water will not be ignoable and will occur significant
Economy	User charge will increase upto monthly 1500 yen (1.5*QA17) compared with the present charge monthly 1000 yen (QA 17).	User charge will increase upto monthly 1500 yen (1.5*QA17) compared with the present charge monthly 1000 yen (QA 17).	User charge will increase upto monthly 2000 yen (2.0*QA17) compared with the present charge monthly 1000 yen (QA 17).
	☐	☐	☐

Please choose the most favour one and check in the bottom box

	Choice 1	Choice 2	Choice 3
Assumed Year	2040	2025	2100
Accessibility (Society)	Satisfying with the regulation for drinking, but sombody minds its smell and taste.	Satisfying with the regulation for drinking and no complaints on the taste and smell	Not satisfying with the regulation for drinking, but no problem on the usage of
Engineering Safety	Daily 4 accidents of leaking water, which is the same as the present situation, from	Daily 4 accidents of leaking water, which is the same as the present situation, from	Daily 20 accidents of leaking water, which is 5 times as much, from the water supply
Environment	Odour, soil contamination, water quality deterioration of discharged water will be ignorable.	Odour, soil contamination, water quality deterioration of discharged water will not be ignoable and will occur significant	The waste water management will be perfect and the problem of odour, soil contamination, water quality deterioration
Economy	User charge will increase upto monthly 1500 yen (1.5*QA17) compared with the present charge monthly 1000 yen (QA 17).	User charge will keep the same level as the present charge monthly 1000 yen (QA 17).	User charge will keep the same level as the present charge monthly 1000 yen (QA 17).
	☐	☐	☐

Please choose the most favour one and check in the bottom box

	Choice 1	Choice 2	Choice 3
Assumed Year	2040	2010	2010
Accessibility (Society)	Satisfying with the regulation for drinking, but sombody minds its smell and taste.	0	Not satisfying with the regulation for drinking, but no problem on the usage of
Engineering Safety	Daily 4 accidents of leaking water, which is the same as the present situation, from	Daily 4 accidents of leaking water, which is the same as the present situation, from	The situation will be improved and there is no leaking accidents except for scheduled
Environment	Odour, soil contamination, water quality deterioration of discharged water will be ignorable.	Odour, soil contamination, water quality deterioration of discharged water will be ignorable.	Odour, soil contamination, water quality deterioration of discharged water will not be ignoable and will occur significant
Economy	User charge will increase upto monthly 1500 yen (1.5*QA17) compared with the present charge monthly 1000 yen (QA 17).	User charge will keep the same level as the present charge monthly 1000 yen (QA 17).	User charge will keep the same level as the present charge monthly 1000 yen (QA 17).
	☐	☐	☐

Do you think that you can understand the meaning of the instruction and sentences of this question?

- Yes
- No

Demographic Character

Please answer your sex.

- Male
- Female

Please tell us your age in number. _________

Do you have any children? If they are under 15 years old, please answer in number in either of using private and public services. If they are over 15 years old, please answer just the number in case your children live independently.

	Before	Private	Public	
0-6 years old (before entering primary school)				×
6-12 years old (primary school)	×			×
12-15 years old (junior high school)	×			×
Over 15 years old (higher education or independence)	×	×	×	

Do you have any grandchildren?

- Yes
- No

This survey requires the identification of the resident area. Please answer the name of the municipality.

Name of municipality ___________________________

How long have you lived there?

______years

How long do you expect to continue to live there?

- Within one year
- Within five years
- Within 10 years
- Over 10 years

In terms of your occupation or the course where you study, please answer the following questions

SQ1. Do/did you study or work for civil engineering or architectures?

- Yes
- No

SQ2. Do you have any family business, properties, knowledge or traditional anything e.g. agri-fields, forests, traditional technique which should be succeeded?

- Yes
- No

Please answer gross annual household income.

- Less than one million yen (£6,800/ year, £1.00=147JPY)
- Over one million yen and less than three million yen (£20,400/ year, £1.00=147JPY)

- Over three million yen and less than five million yen (£34,000/ year, £1.00=147JPY)
- Over five million yen and less than eight million yen (£54,400/ year, £1.00=147JPY)
- Over eight million yen and less than ten million yen (£68,000/ year, £1.00=147JPY)
- Over ten million yen (£68,000/ year, £1.00=147JPY)