Investigation of the relation between impacts on infrastructure management and possible casual factors in depopulated municipalities in Japan using binary logit regression analysis

Tetsuji UEMURA*,**
Susana MOURATO*
Masaaki UTO**

*Department of Geography and Environment, London School of Economics and Political Science
** Nomura Research Institute, Ltd.

Address: Flat 1, London House, 13 Craven Hill, London, W2 3EN, UK.
Mobile: +44-(0)-7832-272-488
e-mail: t.uemura@lse.ac.uk, uemuratetsuji@yahoo.co.jp, t-uemura@nri.co.jp

Abstract (100)

Japan has been in the process of depopulating since 2006. Population decline will variously affect infrastructures. Various impacts on infrastructure management in depopulated regions in Japan have already occurred, but the occurrences are not uniform. This study, therefore, aims at investigating the relations between the impacts and their latent casual factors with statistical methodology, with the aim of preventing future impacts from occurring.

The results of the analysis suggest that population decline is not necessarily the main causal factor of the impacts. Financial constraints in depopulated municipalities are a more significant potential causal factor on infrastructure management.

Key words

Impacts of population decline, infrastructure management, logit regression analysis, population decline, sustainable development

1 Introduction

The population in Japan has been declining since 2006 (National Institute of Population and Social Security Research 2006). Population decline affects various aspects of society (Kuckshinrichs et al. 2006: Table 1) and social care issues are particularly known to be typical fields affected by population decline (Lux 2008). Similarly, infrastructures are also expected to be affected significantly by population decline (Kuckshinrichs et al. 2006; Lux 2008).

	Key demographic feature		
	Decreasing population	Ageing	New regional distribution
Economic and social systems	++	++	+
End-use products	+	+	-
Personal./institutional infrastructure	+	++	+
Grid-bound infrastructures	++ [Efficiency, capacity reduction]	+(+) [User behaviour]	++ [Demand, capacity]

-: no significant pressure
+: significant pressure
++: high pressure
Source: Kuckshinrichs et al. 2006: table 1.

Table 1 Demographic key feature and pressure on system

It has been pointed out that in eastern Germany, which suffered from rapid population decline due to reunification, user charges for water consumption and the sanitation service have increased, and network efficiency has worsened, due to population decline. Furthermore, water quality in the distribution pipes has degraded and odour from sanitation pipes has occurred (Moss 2003; Moss 2004; Moss 2008; Koziol 2006; Hummel and Lux 2007; Lux 2008). An efficiency decline in the supply of heat could also be observed (Koziol 2004). With regard to the transport network, road construction is expected to continue even in a depopulated society. This is likely to cause an increased tax burden on the German population, and though domestic automotive travel is estimated to decline, international freight trucks' travel is expected to increase due to EU enlargement (Just 2004). A reduction in the number of education facilities by 30% is also considered owing to an expected 12% decline in pupils by 2050. The financial demands of education will, however, not necessarily decline and the financial burden on parents may be increased even in depopulated regions because it is a strategic and, really, a political matter (Just 2004). In addition, general public buildings, e.g. city halls, will deteriorate owing to the lack of funds available to maintain them, and the number of public officers, some of whom engage in the management of infrastructures, will probably also be reduced (Just 2004).

It is considered that the process of occurrence of the impacts of population decline is complicated. For instance, it has been pointed out that the process of infrastructures shrinking owing to population decline is expected to pass through the following process: that is, firstly, a decline in the consumption of infrastructure service owing to technology changes and users' behavioural changes; secondly, a decline in the consumption of infrastructure services owing to migration, sometimes with diffusion; thirdly, a decline in the consumption of infrastructure service owing to population decline; fourthly, a decline in the provision of services due to closure of plants and downsizing the capacity of equipment; and finally, a reduction in the infrastructure network (Koziol 2004).

It is difficult to analyse these impacts of population decline on infrastructure management comprehensively because of their various and complicated characters and different circumstances due to location. To classify and analyse the impacts themselves and their causalities in detail, it is necessary to establish an analytical framework, and the concept of sustainability has occasionally been used for the discussion of this topic (Kuckshinrichs et al. 2006; Uemura and Mourato 2008b). Specifically, taking the nature of infrastructure into consideration, it is natural to analyse the impacts using the four aspects of infrastructure sustainability, i.e. society, engineering, environment and economy (Dasgupta and Tam 2005; Sahely et al. 2005; Uemura and Mourato 2008b). This study, therefore, employs the sub-aspects of infrastructure sustainability, especially focusing on the social, engineering and economic aspects of the four, and investigates the relation between the occurrence of the impacts and their latent casual factors from among those aspects.

It is assumed that the concrete subsets of infrastructure sustainability are: the amount of infrastructure; accessibility to infrastructure; deteriorating security owing to derelict infrastructures (the social aspect); deteriorating engineering safety owing to time passing and inappropriate management of infrastructures (the engineering perspective); and increases in the user financial burden or people's tax burden in order to develop and maintain infrastructures (the economic aspect) (Uemura and Mourato 2008b). These impacts have been observed in some depopulated municipalities, but not in others (Uemura et al. 2008d). Anticipation of which factors cause the impacts on infrastructure management in depopulated regions is considered to be important in order to prevent the impacts from occurring in future depopulated societies. This study, therefore, aims at statistically investigating the relation between assumed causal factors and the impacts, which are: "merging and abolishing infrastructures" (social aspects), "declining maintenance levels" (engineering aspects) and "increased user charges" (economic aspects).

The structure of this paper is as follows: firstly, methodology will be introduced in section two; particularly, candidates of explanatory variables will be introduced. Analytical results, including the most likely models and resulting independent variables, will be presented in section three along with a discussion of statistical significance. Section four will conclude the whole investigation and mention future research tasks.

2 Methodology

2.1 Objective infrastructure

Based on the results of a preceding survey of interviews with the officers of the depopulated municipalities in Japan (Uemura et al. 2008c), infrastructures managed by municipalities were categorised into seven types; these are shown in Table 2.

Table 2 Objective types of infrastructure

Types	Examples
Education	Primary, secondary (junior high) schools and kindergartens (nurseries)
Public housing	Public housing
Lifestyle-related facilities	• Social education facilities (library, gymnasium, etc.) • Social care facilities (public health centre, public hospitals, other social care facilities) • Sanitation, solid waste management facilities (excluding drainage and waste water management) • Community facilities • Public parks
Water supply and waste water management	Water supply and waste water management facilities
Transport	Terminals for ferries, aviation, new transport systems and public railway services (including public-private joint operations)
Road	Roads managed by municipalities
Emergency and disaster services	Anti-landslide, flood control, coastal erosion prevention, anti-sand dams (developed or managed by municipalities)

2.2 Modelling framework

Potential variables for regression analysis were selected according to the results of the literature review and the preceding interviews on this issue.

First, as a result of the literature review, the difference between urban and rural areas, and the difference in the speed of population decline, could be considered as factors relating to the impacts of population decline on infrastructure management. It has also been argued that infrastructure types can affect the extent or occurrence of the impacts (Uemura & Mourato 2008a). Next, as a result of the interviews of officers of depopulated municipalities in Japan, it was strongly indicated that geographical character, governmental reform, amount of infrastructure, industrial structures and the financial situation of public finance institutions should be candidates for investigation (Uemura et al. 2008c).

In summary, six categories – that is, demographic factors; geographical factors including both the differences between urban and rural areas, and geographical aspects such as mountainous and plain areas; the amount of infrastructure; government reform; the financial situation of the municipalities; and the types of infrastructure – were selected as explanatory variables. Details and concrete variables will be introduced in the next section.

2.3 Data collection methods

The dataset for the following analysis was collected by a mail survey of the officers in depopulated municipalities in Japan. The survey asked about the impacts of population decline on infrastructure management and was conducted between August and October 2008. The questionnaire was distributed to the 919 municipalities whose population declined between 1975 and 2000 and the response rate was almost 50% (Uemura et al. 2008d). Further data for the dataset was collected from public statistics available on the website provided by the government of Japan.

2.4 Analytical method

2.4.1 Dependent variables

Figure 1 shows the simple results of the mail survey with respect to "increase in user charge", "decline in maintenance level" and "merging and abolishing infrastructures" which were considered as dependent variables in the following regression analysis. Note that, in this paper, "increase in user charge", "decline in maintenance level", and "merging and abolishing infrastructures" are not specified for each particular infrastructure. For example, an increase in the user charge means that one depopulated municipality has increased the user charge for any infrastructure. Of course, the occurrence of the impacts depends on the infrastructure types, and this relation should be detectable with the dummy variables of infrastructure sectors. In addition, it is natural that the relation between the impact and potential explanatory variables in each infrastructure should also be investigated, but the aim of this study is to conduct a comprehensive analysis. Such segmented analysis should, therefore, be conducted in another study.

Subsequently, the situations of the assumed impacts with regard to the mail survey results are reviewed.

Responses showed that "merging and abolishing infrastructures" had occurred in education in almost 80% of depopulated municipalities. 16% to 20% of depopulated municipalities also merged or abolished their public housing and lifestyle-related facilities. Roads and anti-disaster facilities, such as levees, however, barely merged and abolished.

In terms of a "decline in maintenance level", because the water and waste water sectors are regulated by water quality, questions were not included in the mail survey. With regard to other infrastructures, transport was the infrastructure with the lowest reported decline in maintenance (3.9% of depopulated municipalities), and 22.2% of depopulated municipalities decreased the maintenance level of snowploughing and cleaning of roads (which was the highest reported).

On the other hand, in terms of the "increase in user charge", less than 30% of depopulated municipalities increased the user charge for the water and waste water sector. In addition, 15% of them also raised the user charge for lifestyle-related facilities such as gymnasiums, social care facilities and transport. Only 2.8%, however, increased the rent of public houses.

Not all of the depopulated municipalities answered the questions regarding the impacts but the responses of those who did can be regarded as enough for the following regression analysis.

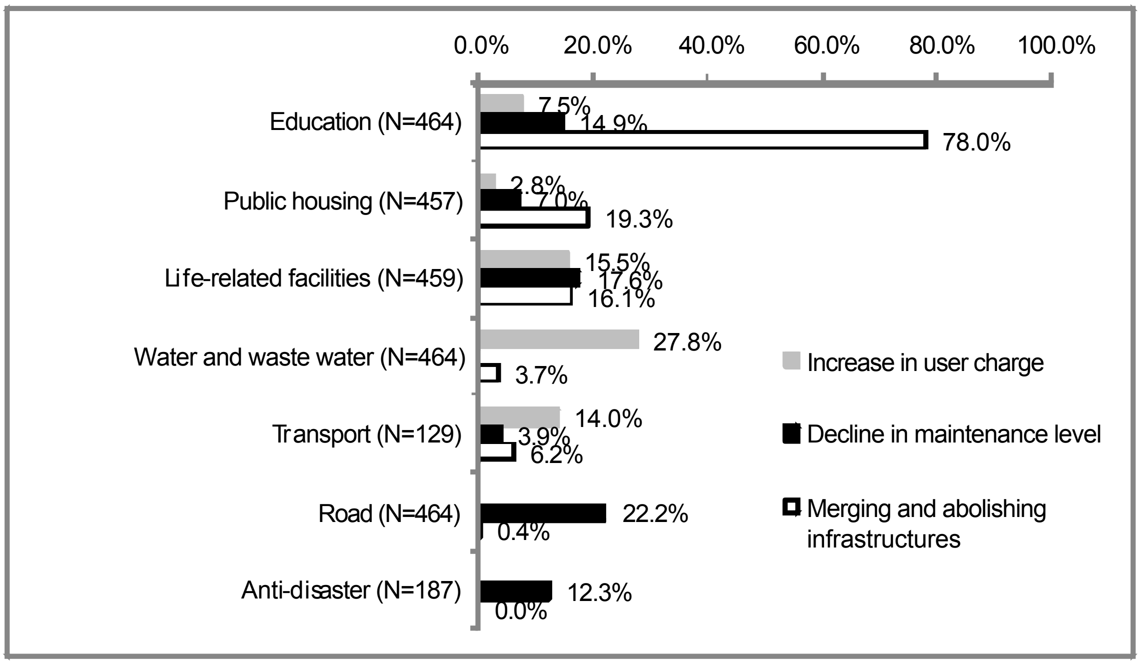

Figure 1 Responses considered as dependent variables in the mail survey

2.4.2 Explanatory variables

In terms of the five potential casual factors of the impacts of population decline discussed in section 2.1, the following variables (shown in Table 3) were considered as explanatory variables in the regression analysis of data obtained from the mail survey and available official statistics. The categories in Table 3 correspond to the potential casual variables discussed in 2.1; the explanations show the meanings of variables; and the data types show the character of the data.

First, the dummy variables on the types of infrastructure were prepared. These are necessary in order to discuss the differences in the occurrence of the impacts among infrastructure types.

Second, the rate of population decline was considered as one of the demographic change factors. The rate of population decline is defined in Equation 1,

$$PDR(n) = (P_{2005} - P_{2005-n}) / P_{2005-n} \qquad (1)$$

where, P_{2005-n} is the population of the year of 2005-n. e.g. PDR 30 is calculated as the population in 2005 and compared with the population in 1975.

The minus sign indicates that the more the population declines, the more impacts will occur. In addition, because it is considered that the different periods of population decline – i.e. long-term population decline (for example, twenty years), or short-term population decline (for example five years) – will make a difference to the occurrence of impacts on infrastructure management, the different population decline rates were prepared from five to thirty years at five year intervals. Next, the size of population was considered. This is because the population size of municipalities will dictate the size of the authority. The percentage of elderly people per total population was also considered. This number could be regarded as a preceding indicator of population decline. Not only the abovementioned demographic factors, but also the causes of population decline such as natural decline, and decline in the main industries in the region as a cause of social decline, were considered. The reason why the causes of population decline should be considered is that previous research has observed a small social change in regions whose population has been lost only by natural decline. We consider factors of social decline to be "going to higher education or getting jobs", "abolishing branches", "finishing mega public works", "decline in main industry" and "abolishing public transport service". Finally, the occurrence of population decline, that is, even or impartial population decline within the municipality, was considered.

Third, concerning geographical character, the difference between rural and urban areas was considered in terms of the percentage of the population in densely inhabited districts per total population in the municipality. A geographical constraint was calculated as the number of inhabitable areas per total areas in the municipality. In addition, according to the preceding interview, when primary industry, which is agriculture, forestry and so on, becomes the main industry in the region it can sustain the status of the population decline regarding infrastructure management. Therefore, the regional character of industry was considered in terms of the rate of the population engaged in primary industry. Note that the mining sector is not included in the category of primary industry in Japan.

Fourth, with respect to the amount of infrastructure, the official statistics on education facilities, libraries and community facilities, urban parks, waste water facilities and length of roads were converted into a percentage of the area. Binary data, whether owned or not by the municipality, were used for public housing, transport and anti-disaster facilities, owing to data constraints.

Fifth, with regard to administration reform in the municipalities, "reorganising public services provision for the residents", "merging and abolishing public facilities", "increasing or introducing contracting out", "downsizing the financial size of municipalities", "rev iewing the salary levels of public officers", "introducing e-government to the municipalities" and "not enough administrative reform conducted" were considered as variables and their data came from the mail survey results for depopulated municipalities in Japan.

Table 3 Entered variables in the regression analysis

Category		Variables	Explanation	Data type
explanatory	Dummies	D_edu	Dummy of education sector	Binary
		D_ph	Dummy of Public housing sector	Binary
		D_Ls	Dummy of the Life supporting sector	Binary
		D_ww	Dummy of the water and waste water sector	Binary
		D_trans	Dummy of the transport sector	Binary
		D_road	Dummy of the road sector	Binary
		D_disas	Dummy of anti-disaster sector	Binary
	Demographic change	PDR(30)	Population decline rate for 30 years (1975->2005)	Percentage
		PDR(25)	Population decline rate for 25 years (1980->2005)	Percentage
		PDR(20)	Population decline rate for 20 years (1985->2005)	Percentage
		PDR(15)	Population decline rate for 15 years (1990->2005)	Percentage
		PDR(10)	Population decline rate for 10 years (1995->2005)	Percentage
		PDR(5)	Population decline rate for 5 years (2000->2005)	Percentage
		PopSize	Population size (thousand) in 2005	Number
		Elderly	Poplulation size over 65 years old in 2005 per Population size (thousand) in 2005 in the municipality	Percentage
		ND	Causes of population decline: Natural Decline (yes=1/no=0)	Binary
		SD_ER	Cuases of population decline: Social Decline: transfer to go to higher education or to get jobs (yes=1/no=0)	Binary
		SD_AB	Cuases of population decline: Social Decline: Abolition of company/ government branches (yes=1/no=0)	Binary
		SD_AT	Cuases of population decline: Social Decline: Abolition of public transport service (mostly provided by the private sector)(yes=1/no=0)	Binary
		SD_FC	Cuases of population decline: Social Decline: Finishing mega-construction (yes=1/no=0)	Binary
		SD_DI	Cuases of population decline: Social Decline: Decline in the main industry in the municipality (yes=1/no=0)	Binary
		Dec_Pat	Population decline pattern in the municipality (1=apart/ 0=equally)	Binary
	Area	Area	Area in the municipality	Number
	Urban/ Rural	DIDPop	Population in the densily inhabited district / total population in each municipality (this is the sign of urban) in 2005	Percentage
	Geographic character	HabitableA	Habitable area / total area in 2006	Percentage
	Industry	PrimeIndustry	population engaged in the primary industry (agriculture, fishery, forestr but excluding mining)/ working population in each municipality in 2005	Percentage
	Stock amount of infra	Schools	Number of Schools in 2005 per the area	Percentage
		Housing	the situation of owning public housing(yes=1/no=0)	Binary
		Facilities	Number of public facilities in 2005 per the area	Percentage
		Parks	Number of urban park in 2005 per the area	Percentage
		Tanks	Number of those who can't use waste water management, that is, the number of simple septic tank and earth closet in 2004 (thousand) per the area	Percentage
		Transport	Existance of transport facilities (yes=1/ no=0) in q14_1 of the mail survey for the municipalities	Binary
		Road	Length of municipalities' road (km) in 2006 per the area	Percentage
		A-Disaster	Situation of managing anti-disaster facilities in q16_1 of mail questionnaire for the municipalities (1=managing anti-diaster infra/ 0=No)	Binary
	Governmental reform	re_P.Service	reorganizing public services for residents in the q3_1_1 of the mail survey	Binary
		M&A_Facilities	merging and abolishing public facilities in the q3_1_2 of the mail survey	Binary
		Contrac-out	increasing or introducing contracting out in the q3_1_3 of the mail survey	Binary
		Downsize_Finance	downsizing financial size of the municipality in the q3_1_4 of the mail survey	Binary
		Re_Salary	reviewing of salary level of officers in the q3_1_5 of the mail survey	Binary
		e-Gov	introducing e-government to the municipality in the q3_1_6 of the mai survey	Binary
		Not_Enough	not enough reform in the q3_1_8 of the mail survey	Binary
	Financial situation	Reve-Expend	revenue-expenditure balance (%) in 2005	Percentage
		Debt-Repay	debt repayment ratio (%) on the total budgetary size in 2005	Percentage

Finally, as regards the variables of the financial situation, the revenue-expenditure balance in percentage and debt-repayment outlay in comparison with the total budget size in percentage, were also considered. It was assumed that the former represented healthiness of financial condition and the latter represented the degree of financial flexibility in the municipalities.

2.4.3 Dataset

In order to manage the data on different types of infrastructure at the same time, the data were stacked as shown in Table 4.

Table 4 Image of stacked data

	Dependent variables	Explanatory variables				
		Dummy of infrastructure typ			Other variables	
ID	Impact	Education	Public Housing	…	PDR(5)	…
Municipality A	1	1	0	…	0.01	…
Municipality B	0	1	0	…	0.10	…
Municipality C	0	1	0	…	0.03	…
Municipality D	1	1	0	…	0.06	…
Municipality E	1	1	0	…	0.02	…
…	…	…	…	…	…	…
Municipality A	1	0	1	…	0.01	…
Municipality B	1	0	1	…	0.10	…
Municipality C	0	0	1	…	0.03	…
Municipality D	0	0	1	…	0.06	…
Municipality E	0	0	1	…	0.02	…
…	…	…	…	…	…	…

2.4.4 Binary logit analysis

When a dependent variable is discrete data, either a probit model or a logit model (logistic regression model) is generally used for analysis. Otherwise, derivatives considering random effects or fixed effects for the panel data are used. The data in this case are 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 normal distribution or logistic distribution on the error distribution. The difference between them is not so significant when the response rate of dependent variables is approximately 50%. When the response rate is, however, either extremely small or very large, it is recognised that the logit model tends to produce larger estimation results than those of the probit model. Although there are many arguments about which model is superior, there is no definitive conclusion (Greene 2003). In this case, therefore, the logit model was applied to the data for ease of estimation.

The initial model for the binary logit regression analysis was identified in Equation 2.

$$
\begin{aligned}
&Logit(Impacts) \\
&= \alpha + \beta_1 D\_edu + \beta_2 D\_ph + \beta_3 D\_ls + \beta_4 D\_ww + \beta_5 D\_trans + \beta_6 D\_road + \beta_7 D\_disas \\
&+ \beta_8 PDR(t) + \beta_9 PopSize + \beta_{10} Elderly \\
&\quad + \beta_{11} ND + \beta_{12} SD\_ER + \beta_{13} SD\_AB + \beta_{14} SD\_AT + \beta_{15} SD\_FC + \beta_{16} SD\_DI \\
&\quad + \beta_{17} Dec\_Pat \\
&+ \beta_{18} Area + \beta_{19} DIDPop + \beta_{20} HabitableA + \beta_{21} 1stIndustry \\
&+ \beta_{22} Schools + \beta_{23} Housing + \beta_{24} Facilities + \beta_{25} Parks + \beta_{26} Tanks + \beta_{27} Transport \\
&\quad + \beta_{28} Road + \beta_{29} A\_Disaster \\
&+ \beta_{30} re\_P.Service + \beta_{31} M\&A\_Facilities + \beta_{32} Contract\_out + \beta_{33} Downsize\_Finance \\
&\quad + \beta_{34} Re\_Salary + \beta_{35} e-Gov + \beta_{36} Not\_Enough \\
&+ \beta_{37} Reve\_Expend + \beta_{38} Debt\_Repay
\end{aligned} \tag{2}
$$

$$
\begin{aligned}
&where \\
&t = 5,10,15,20,25,30 \quad and \quad each\ of\ the\ variables\ are\ the\ same\ as\ in\ Table\ 3
\end{aligned}
$$

In the process of estimation, the backward-stepwise method, with Wald statistics 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 3 were entered in the binary logit regression model. Afterwards, the variables with insignificant Wald statistics were removed from the updated model.

2.5 Fitness test

As a way of confirming the significance and the fitness indicator of the models, and comparing the explanatory power of the models, X^2 test, Nagelkerke's R^2 (Nagelkerke 1991, see Equation 3) and AIC (Akaike Information Criteria) were used for each.

$$
\overline{R}^2_{\text{Nagelkerke}} = \frac{1 - \left\{ \dfrac{L(0)}{L(\hat{\beta})} \right\}^{\frac{2}{n}}}{1 - \{L(0)\}^{\frac{2}{n}}} \tag{3}
$$

3 Results and discussion

Table 5 shows the analytical results. All selected models satisfy with 1% statistical significance. Within these significant models, the most relevant models based on AIC are PDR15 in "merging and abolishing infrastructures" and PDR25 in "decline in the maintenance level" and "increase in the user charge".

Next, the correlations of selected explanatory variables are checked and, after that, the details are explained.

Table 5 Summary of the results of binary logit regression analysis on the impacts of population decline on infrastructure management

		Increase in user charge			Decline in maintenance level		Merging and abolishing facilities					
		PDR25	PDR30	Other than PDR25, PDR30	Other than PDR25	PDR25	PDR5	PDR10	PDR15	PDR20	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
	Nagelkerke R Square	0.233	0.231	0.108	0.193	0.196	0.585	0.593	0.595	0.593	0.591	0.591
	AIC	1,188	1,189	2,363	1,352	1,351	1,264	1,252	1,246	1,251	1,254	1,255
Dummies	D_edu	-0.885 ***	-0.892 ***	-1.336 ***	-0.369 **	-0.362 **	6.839 ***	6.949 ***	6.994 ***	6.969 ***	6.947 ***	6.941 ***
	D_ph	-1.501 ***	-1.495 ***	-0.844 ***	-0.691 ***	-0.703 ***	4.326 ***	4.355 ***	4.375 ***	4.368 ***	4.359 ***	4.358 ***
	D_Ls						3.717 ***	3.754 ***	3.777 ***	3.776 ***	3.767 ***	3.764 ***
	D_ww	1.212 ***	1.207 ***				2.142 ***	2.160 ***	2.180 ***	2.183 ***	2.176 ***	2.173 ***
	D_trans				-1.845 ***	-1.863 ***	2.338 ***	2.353 ***	2.354 ***	2.363 ***	2.358 ***	2.351 ***
	D_road				1.119 ***	1.113 ***						
	D_disas											
	PDR5											
	PDR10							-7.645 ***				
	PDR15								-6.667 ***			
	PDR20									-4.353 ***		
	PDR25	-1.417 *				-1.531 *					-3.364 ***	
	PDR30											-2.850 ***
	PopSize	-0.007 ***	-0.008 ***		-0.006 **	-0.006 **						
	Elderly				-4.193 ***	-5.428 ***		-4.329 **	-5.181 ***	-4.533 ***	-4.502 **	-4.604 **
	ND											
	SD_ER											
	SD_AB											
	SD_AT	0.685 **	0.775 **	0.671 ***								
	SD_FC				0.780 ***	0.670 **						
	SD_DI	0.309 *	0.362 **				0.415 **	0.318 **	0.307 *	0.302 *	0.308 *	0.318 **
Demographic change	Dec_Pat				-0.537 ***	-0.494 **						
Area	Area						0.001 *	0.001 ***	0.001 ***	0.001 ***	0.001 ***	0.001 ***
Urban/ Rural	DIDPop						0.915 ***	0.889 **	0.799 **	0.745 *	0.695 *	0.707 *
Geographic character	HabitableA	1.374 ***	1.193 ***		1.322 ***	1.381 ***						
Industry	PrimeIndustry						-1.432 ***	-1.525 **	-1.800 **	-1.871 **	-1.963 **	-1.997 ***
Stock amount of infra	Schools	0.439 *	0.514 **									
	Housing				-1.593 ***	-1.591 ***						
	Facilities											
	Parks											
	Tanks											
	Transport											
	Road	-0.090 *	-0.103 **		-0.084 **	-0.072 *						
	A-Disaster	0.340 **	0.349 **	0.196 **	0.354 **	0.348 **						
Governmental reform	re_P.Service	0.602 ***	0.654 ***		0.727 ***	0.683 ***						
	M&A_Facilities						NA	NA	NA	NA	NA	NA
	Contrac-out	0.512 **	0.461 *									
	Downsize_Finance				0.401 ***	0.405 ***	0.404 ***	0.417 ***	0.414 ***	0.424 ***	0.424 ***	0.418 ***
	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	-2.943 ***	-2.550 ***	0.124	-0.111	-0.064	-5.782 ***	-5.216 ***	-5.057 ***	-5.097 ***	-4.974 ***	-4.895 ***

Note: * 10% significance、**5% significance、***1% significance

3.1 Correlation check of selected independent variables

Table 6 to Table 8 show the results of correlation checks among the selected explanatory variables in each model. The absolute values of almost all correlation values are less than or equal to 0.3 and this means that there is almost no correlation among those variables. Some of the highly correlated variables are dummy variables for infrastructure types correlated with each other, but these are natural because most municipalities have multiple infrastructures of the same types. Of the remainder, a slightly problematic correlation is that between the rate of population decline and the rate of the elderly per total population; however, these two variables should both be included in this analysis in order to distinguish the effect of population decline and ageing regarding this issue. Accordingly, these selected models and explanatory variables do not have any theoretical problem included for discussion of them in the following part of this paper.

Table 6 Correlation check among selected explanatory variables in the PDR15 model of "merging and abolishing infrastructures"

	Constant	D_edu	D_ph	D_Ls	D_ww	D_trans	PDR15	Elderly	SD_DI	Areakm2	DIDPop	PrimeIndustry	Downsize_ Finance
Constant	1.000	-.799	-.798	-.801	-.765	-.723	-.101	-.496	-.013	-.185	-.286	-.136	-.069
D_edu	-.799	1.000	.963	.963	.920	.865	-.078	-.034	.029	.054	.024	-.023	.037
D_ph	-.798	.963	1.000	.964	.924	.868	-.031	-.010	.015	.019	.010	-.005	.014
D_Ls	-.801	.963	.964	1.000	.925	.870	-.030	-.006	.012	.017	.006	-.004	.012
D_ww	-.765	.920	.924	.925	1.000	.834	-.016	.000	.003	-.005	.001	.008	.003
D_trans	-.723	.865	.868	.870	.834	1.000	-.011	.009	-.008	-.010	.008	.004	.004
PDR15	-.101	-.078	-.031	-.030	-.016	-.011	1.000	.537	.150	.014	.016	.118	-.025
Elderly	-.496	-.034	-.010	-.006	.000	.009	.537	1.000	-.064	.148	.293	-.008	-.048
SD_DI	-.013	.029	.015	.012	.003	-.008	.150	-.064	1.000	-.072	.037	.123	-.155
Areakm2	-.185	.054	.019	.017	-.005	-.010	.014	.148	-.072	1.000	-.010	-.122	.023
DIDPop	-.286	.024	.010	.006	.001	.008	.016	.293	.037	-.010	1.000	.386	-.106
PrimeIndustry	-.136	-.023	-.005	-.004	.008	.004	.118	-.008	.123	-.122	.386	1.000	-.018
Downsize_Finance	-.069	.037	.014	.012	.003	.004	-.025	-.048	-.155	.023	-.106	-.018	1.000

Note: the grey colour in the table shows that the absolute value of the correlation is greater than or equal to 0.3.

Table 7 Correlation check among selected explanatory variables in the PDR25 model of "decline in the maintenance level"

	Constant	D_edu	D_ph	D_trans	D_road	PDR25	PopSize	Elderly	SD_FC	Dec_Pat	HabitableA	Housing	Road	ADisaster	re_P.Service	Downsize_Finance	DebtRepay
Constant	1.000	-.109	-.056	-.024	-.067	-.031	-.037	-.536	.043	-.143	-.279	-.659	-.235	-.011	-.097	.076	-.273
D_edu	-.109	1.000	.338	.160	.414	-.017	.000	.023	-.009	.006	.014	-.017	.003	.081	.018	-.026	.001
D_ph	-.056	.338	1.000	.130	.330	.035	-.005	.031	.014	.004	.011	-.041	.010	.070	-.005	-.024	-.012
D_trans	-.024	.160	.130	1.000	.155	.025	.004	.025	-.009	.012	.004	-.021	-.008	.024	.014	-.015	-.026
D_road	-.067	.414	.330	.155	1.000	.007	-.007	-.056	.031	-.032	.053	-.034	-.016	.106	.050	.012	.034
PDR25	-.031	-.017	.035	.025	.007	1.000	-.094	.418	.211	-.122	-.084	.003	-.146	.021	.124	-.019	.009
PopSize	-.037	.000	-.005	.004	-.007	-.094	1.000	.200	.039	-.061	.057	-.163	-.286	-.085	-.037	-.064	-.016
Elderly	-.536	.023	.031	.025	-.056	.418	.200	1.000	.001	.022	.224	-.045	-.080	-.043	.053	-.071	.021
SD_FC	.043	-.009	.014	-.009	.031	.211	.039	.001	1.000	-.106	.067	.000	-.059	-.052	.046	-.018	-.087
Dec_Pat	-.143	.006	.004	.012	-.032	-.122	-.061	.022	-.106	1.000	.007	.087	-.021	-.025	-.024	-.044	.066
HabitableA	-.279	.014	.011	.004	.053	-.084	.057	.224	.067	.007	1.000	-.019	-.481	.174	.026	.046	-.031
Housing	-.659	-.017	-.041	-.021	-.034	.003	-.163	-.045	.000	.087	-.019	1.000	.287	-.081	-.101	-.088	-.068
Road	-.235	.003	.010	-.008	-.016	-.146	-.286	-.080	-.059	-.021	-.481	.287	1.000	-.087	-.021	-.116	.179
ADisaster	-.011	.081	.070	.024	.106	.021	-.085	-.043	-.052	-.025	.174	-.081	-.087	1.000	-.010	.042	-.034
re_P.Service	-.097	.018	-.005	.014	.050	.124	-.037	.053	.046	-.024	.026	-.101	-.021	-.010	1.000	-.180	-.069
Downsize_Finance	.076	-.026	-.024	-.015	.012	-.019	-.064	-.071	-.018	-.044	.046	-.088	-.116	.042	-.180	1.000	-.092
DebtRepay	-.273	.001	-.012	-.026	.034	.009	-.016	.021	-.087	.066	-.031	-.068	.179	-.034	-.069	-.092	1.000

Note: the grey colour in the table shows that the absolute value of the correlation is greater than or equal to 0.3.

Table 8 Correlation check among selected explanatory variables in the PDR25 model of "increase in the user charge"

	Constant	D_edu	D_ph	D_ww	PDR25	PopSize	SD_AT	SD_DI	HabitableA	Schools	Road	ADisaster	re_P.Service	Contracout	eGov	ReveExpend
Constant	1.000	-.171	-.100	-.276	.594	-.183	.051	-.055	-.455	.162	-.032	-.162	-.255	-.487	.034	-.282
D_edu	-.171	1.000	.222	.398	-.015	.014	-.010	-.010	.005	-.043	.018	.002	-.004	-.014	.013	.007
D_ph	-.100	.222	1.000	.272	.016	.008	-.033	-.007	-.005	-.029	.028	.001	-.015	-.017	.012	.020
D_ww	-.276	.398	.272	1.000	-.032	-.042	.042	.020	.068	.017	-.013	.045	.024	.029	-.026	-.018
PDR25	.594	-.015	.016	-.032	1.000	-.265	.167	.202	-.246	.193	-.153	.033	.151	-.135	.001	-.120
PopSize	-.183	.014	.008	-.042	-.265	1.000	.019	-.063	.068	-.448	-.078	-.075	-.082	-.038	-.035	.180
SD_AT	.051	-.010	-.033	.042	.167	.019	1.000	-.055	-.019	.011	-.041	-.089	.044	.006	-.048	-.029
SD_DI	-.055	-.010	-.007	.020	.202	-.063	-.055	1.000	.147	.107	-.142	.008	.017	-.063	-.010	-.033
HabitableA	-.455	.005	-.005	.068	-.246	.068	-.019	.147	1.000	-.092	-.394	.186	-.023	.041	-.058	.100
Schools	.162	-.043	-.029	.017	.193	-.448	.011	.107	-.092	1.000	-.504	.038	-.007	.039	.004	.075
Road	-.032	.018	.028	-.013	-.153	-.078	-.041	-.142	-.394	-.504	1.000	-.078	.036	-.058	-.009	-.198
ADisaster	-.162	.002	.001	.045	.033	-.075	-.089	.008	.186	.038	-.078	1.000	.005	-.085	-.088	.051
re_P.Service	-.255	-.004	-.015	.024	.151	-.082	.044	.017	-.023	-.007	.036	.005	1.000	-.148	-.092	-.017
Contracout	-.487	-.014	-.017	.029	-.135	-.038	.006	-.063	.041	.039	-.058	-.085	-.148	1.000	-.081	-.001
eGov	.034	.013	.012	-.026	.001	-.035	-.048	-.010	-.058	.004	-.009	-.088	-.092	-.081	1.000	.009
ReveExpend	-.282	.007	.020	-.018	-.120	.180	-.029	-.033	.100	.075	-.198	.051	-.017	-.001	.009	1.000

Note: the grey colour in the table shows that the absolute value of the correlation is greater than or equal to 0.3.

3.2 Increase in user charge

In terms of "increase in user charges", on the one hand, education and public housing satisfy with 1% statistical significance but the sign of the coefficient is minus which means that the user charges have not increased relatively. On the other hand, waste and waste water also satisfy with 1% statistical significance but the sign of the coefficient is positive which means that the user charge has increased significantly. It can, however, be considered that these differences between the infrastructure sectors reflect the relative response rate among those sectors according to Figure 1.

Next, population decline, which is possibly a main casual factor, was certainly statistically significant for only 25 years, but the level of significance was just 10% which suggests a weak relation between population decline and "increase in user charges" for all infrastructures. This, however, does not suggest a weak relation between them in each infrastructure sector. In this respect, a further sector-focusing analysis is needed.

Population size satisfies with a level of 1% statistical significe but the coefficient is minus which suggests, that the lower the population is, the easier it is to increase the user charge. This is because a lower population means less latent users and causes the vulnerable revenue-expenditure balance to result in a financial deficit regarding the sufficient management of infrastructures.

In the assumed causal factors of population decline, "abolishing public transport" satisfies with 5% statistical significance and "decline in the regional main industry" also satisfies with 10% statistical significance. The reason why a relation between the abolition of public transport and an increase in the user charge can be observed is probably that the user charge tends to be increased before operators abolish public transport, in an attempt to improve the financial situation. In addition, it can be shown that a "decline in the regional main industry" is possibly linked to a decline in the water consumption by the regional main industry, when it is considered that the water and waste water sector constitutes a main portion of the responses on increasing user charges. In the water and waste water sector, fixed costs are a significant portion of the revenue-expenditure structure, so that a population decline causes an increase in the per-contract allocated cost, which is substantially equal to the increase in the user charge.

Some of the geographical conditions are also statistically significant. For example, habitable areas satisfy with 1% statistical significance and the larger the municipality is, the higher is the possibility of increasing the user charge. It is possible to argue that the sectors in which the user charge was raised are water and waste water or transport sectors, and that the larger municipalities, therefore, have to pay more to maintain the infrastructures, so that their profit-loss balance is originally higher than smaller municipalities. Interestingly, on the contrary, the percentage of public buildings, such as libraries and public urban parks, per area in the municipalities is not statistically significant. Regarding this point, two possibilities can be considered. The first is that the data conversion from the actual number of infrastructures to the area-percentage causes dilution of the information because the user charges are strongly related to the actual number of units, and not to the number of units per area. Accordingly, it would not be possible to detect the tendency. The second possibility is that the data for this analysis is too limited; there is a constraint regarding obtaining public statistics on municipal infrastructures, and so additional data on other infrastructures would be expected to improve the analysis.

When considering the detail of each infrastructure sector, the area-rate of education facilities and density of roads satisfies with 10% statistical significance; the more education facilities there are per area and the lower the road density per area, the higher user charges are. Anti-disaster facilities pass the 5% statistical significance test and more anti-disaster facilities tend to bring a higher user charge in the municipalities. It is instinctively understandable that more education and anti-disaster facilities will bring higher user charges; however, it seems slightly strange that a lower road density per areas brings higher user charges. The hint for understanding this point is probably the reminder that most of the municipal roads are streets, and short average road length suggests a small urban area and large rural area in the municipality, which would mean a low population density.

The relations between "increase in the user charge" and other administrative reforms in the depopulated municipalities are as follows: "reviewing service provision" satisfies with 1% statistical significance and "contracting out maintenance works" satisfies with 5% statistical significance. "Promoting e-government" also satisfies with 1% statistical significance but its coefficient sign was minus. This result suggests that the depopulated municipality which asks for more financial burden on users also delays the introduction of policies of e-government.

In terms of financial issues, "net-revenue-expenditure balance" satisfies with 5% statistical significance, but its coefficient was also minus. Accordingly, and naturally, it can be found that the municipalities with a worse financial situation ask for a higher user financial burden.

3.3 Decline in maintenance level

The relation between infrastructure sectors and "decline in maintenance level" is 5% statistically significant in education, public housing and transport, but the results show that maintenance levels did not relatively decline while the maintenance level in the road sector did significantly decline with a 1% statistical level.

In terms of population decline, the same over 25 years significantly relates to the decline in the maintenance level of infrastructures, but the level of it was only 10%, indicating that there is only a weak relation between them. Furthermore, the population size satisfies with 5% statistical significance but its coefficient was minus which means that the municipalities with less population decline also demonstrated less decline in the maintenance levels of their infrastructures. The rate of the elderly also satisfies with 1% level of statistical significance, and with a minus sign of the coefficient suggesting that a lower percentage of the elderly brings a decline in maintenance levels. The reasons for this can not be ascertained from this study but it is worth considering that the municipalities with a high percentage of the elderly have to support the elderly lives, so that they cannot reduce their maintenance works of infrastructures.

With respect to the causes of population decline, the municipalities which have finished mega public works have experienced a decline in their infrastructures' maintenance levels (5% statistical significance). The reason for this can be considered to be the removal of the necessity of maintaining infrastructures for large numbers of vehicles for the construction works. Regarding the pattern of population decline, a partial decline in the depopulated municipalities causes an increased possibility of decline in the maintenance level of infrastructures.

The relation between habitable areas and a decline in the maintenance level of geographical aspects is also significant, with 1% statistical level. The coefficient was plus, so that the wider the habitable areas is, the more possibility to decline in the maintenance level is. This is because the elements of maintenance work are snowploughing and cleaning, and the municipalities with wider habitable areas probably have to concentrate their limited resources on those areas needing such maintenance works.

Some of the results regarding infrastructure amount are also statistically significant. For example, the percentage of public housing per area satisfies with 1% statistical significance and road density also satisfies with 10% significance. The less public housing there is and the lower the road density is, the more possibility there is that maintenance levels in the depopulated municipality will decline. However, in terms of the anti-disaster sector, which is also 5% statistically significant, the more dense the municipality is, the higher is the possibility for a decline in maintenance levels. This is similar to the situation in the increase in user charges.

Those depopulated municipalities which have review their provision of governmental services have also declined in their maintenance level of infrastructures with 1% statistical significance. Similarly, the municipalities which downsized their budget have declined in their maintenance level (1% significance). Furthermore, the municipalities with a high debt repayment ratio in their budgets have declined in their maintenance level with 5% statistical significance. These results suggest that, to mitigate their budgetary rigidity, the municipalities tend to reduce their maintenance costs, which are normally considered as compulsory costs, in order to restore their financial flexibility.

3.4 Merging and abolishing infrastructures

Apart from the dummy variables for the road sector and anti-disaster sector, all of the dummy variables of the infrastructure types satisfy with 1% statistical significance. This means that merging and abolishing infrastructures has not occurred in the specific municipalities but has depended on the characters of infrastructures.

In terms of population decline and merging and abolishing infrastructures, population decline for more than 10 years is significantly related to merging and abolishing infrastructures with 1% statistical significance.

It was also found that a lower rate of the elderly per total population is linked to the merging and abolishing of infrastructures (1% statistical significance). A possible reason for this is that those municipalities with a high rate of elderly people have understood the problems caused by an aging population for 10 to 20 years, and have probably reduced the development of additional infrastructures.

Concerning the causes of population decline, only "decline in the regional main industry" related to merging and abolishing the infrastructures but, even in the highly significant model of PDR15, its statistically significant level is only 10%, so that it cannot be determined whether there is a strong relation between them.

Geographical factors, such as habitable areas and the percentage of population within the density inhabited district, were also statistically significant, but their significance level was unstable over the models. The PDR15 model is the model which fits the most closely, however, the levels are over 5% statistically significant. In addition, the rate of primary industry also satisfies with 5% statistical significance but the sign of the coefficient was minus, which indicates that more industrialised areas have experienced the merging and abolishing of infrastructures. Taking geographical and industrial factors mentioned above into consideration, it can be assumed that municipalities have developed plenty of infrastructure in accordance with growth of their urban areas due to industry prosperity, but that they have then suffered from industrial decline and population loss while still retaining large urban areas and a high percentage of the population relying on non-primary industry; as a result, the depopulated municipalities have to reduce the amount of infrastructure.

With respect to administrative reform, it was found that municipalities which have downsized their budgets tend to conduct merging and abolition of their infrastructures.

On the other hand, it was found that population size, unequal population decline within the municipalities, and the amount of infrastructure which was initially assumed to be the result of merging and abolition, were not statistically significantly related to the impact. Furthermore, municipalities' reviewing of governmental service provisions and financial situations also did not statistically relate to the impact, so that it seems that the merging and abolishing of infrastructures is not chosen as a result of policy reform of infrastructure service provisions in the depopulated municipalities, but is a tool for downsizing budgets.

In summary, it can be argued that, when municipalities in which both population decline has become remarkable, and same-sector multi-infrastructure were developed, have to downsize their budget sizes, merging and abolishing of infrastructures will occur.

4 Conclusion

This study investigated the relation between latent casual factors and impacts, particularly "increase in user charge", "decline in maintenance level" and "merging and abolishing of infrastructures", regarding infrastructure management in depopulated municipalities in Japan.

The analysis and results showed that there are not necessarily significant relations between some of the impacts and population decline. Rather, the results suggested that "decline in maintenance level" and "increase in user charge" have occurred as a part of administrative reforms such as shrinking budget size in order to cope with unbalanced budgets in depopulated municipalities. Similarly, "merging and abolishing infrastructures" relates statistically significantly to the population decline, but it is also suggested that this was executed in the process of shrinking budget size. In other words, the impacts on infrastructures in depopulated municipalities do not directly connect to the population decline, but indirectly connect to it via financial matters, which form an intermediate step. Furthermore, it was found that this indirect process suggests that the question of how public officers should cope with the financial situation in depopulated municipalities is a key latent factor of this issue. In this respect, it should be noted that the local tax revenue transfer programmes from the central government in Japan could have supported the budget size of depopulated municipalities without regard for the population decline in the region.

In the future, to verify the suggested latent structure of this issue, it is expected that structured equation modelling will be applied to this dataset.

5 References

1) Dasgupta, S. and Tam, E. (2005) Indicators and framework for assessing sustainable infrastructure. *Canadian Journal of Civil Engineering*, 32: 30-44.

2) Greene, W.H. (2003) *Econometric Analysis*. 5th ed. Pearson Education International, New Jersey.

3) Hummel D. and Lux, A. (2007) Population decline and infrastructure: The case of the German water supply system. *Vienna Yearbook of Population Research 2007*, 167-191.

4) Just, T. (2004) Demographic developments will not spare the public infrastructure. *Deutsche Bank Research*, June: 1-24.

5) Koziol, M. (2004) The consequences of demographic change for municipal infrastructure. *German Journal of Urban Studies*, 44,

http://www.difu.de/index.shtml?/publikationen/dfk/en/04_1/04_1_koziol.shtml (31 July 2008, available).

6) Koziol, M. (2006) Dismantling Infrastructure. In: Oswalt, P. ed., *Shrinking Cities*, vol. 2, Hatje Cantz, 76-79, Germany..

7) Kronenberg, T. (2008) The impact of demographic change on energy use and greenhouse gas emissions. STE preprint 2008-12, Institute für Energieforschung, Systemforschung und Technologische Entwicklung, Jülich.

8) Kronenberg, T. and Moeller-Uehlken, K. (2008) Demographic change as a challenge for regional infrastructure planning. STE preprint 2008-11, Institute für Energieforschung, Systemforschung und Technologische Entwicklung, Jülich.

9) Kuckshinrichs, W., Tivig, T., Scheele, U., W.Krewitt, H.Keimel and B. Lenz (2006) Infrastructure and demographic development - Framework conditions and challenges in the context of sustainable development. STE Preprints 21.

10) Lux, A. (2008) Shrinking cities and water supply. In: Hummel, D. ed. *Population Dynamics and Supply System*, Campus, 161-179, Germany.

11) McFadden, D. (1974) The measurement of urban travel demand. *Journal of Public Economics*, 3: 303-328.

12) Moss, T. (2003) Utilities, land-use change, and urban development: Brownfield sites as 'cold-spots' of infrastructure networks in Berlin. *Environmental and Planning*, A 35: 511-529.

13) Moss, T. (2004) Institutional restructuring, entrenched infrastructure and the dilemma of overcapacity. In: Southerton, D., Chappells, H. and Vliet, B.V. ed., *Sustainable consumption: The implication of changing infrastructure of provision*. Edward Elgar, Cheltenham, 97-112.

14) Moss, T. (2008) 'Cold spots' of urban infrastructure: 'Shrinking' processes in Eastern Germany and the modern infrastructural ideal. *International Journal of Urban and Regional Research*, 32: 436-451.

15) Nagelkerke, N.J.D. (1991) A note on a general definition of the coefficient of determination. *Biometrika*, 78: 691-692.

16) National Institute of Population and Social Security Research (2006) *Nihonno shourai suikei jinkou (Projection of population in Japan)*. National Institute of Population and Social Security Research, Tokyo, Japan.

17) Sahely, H., Kennedy, C. and Adams, B. (2005) Developing sustainability criteria for urban infrastructure systems. *Canadian Journal of Civil Engineering*, 32: 72-85.

18) Uemura, T. and Mourato, S. (2008a) Jinkou gensho ga syakasihon ni ataeru eikyo (Impacts of population decline on infrastructure management: literature review). Paper presented at the 37th Conference of the

Infrastructure Planning Committee, Japan Society of Civil Engineers, University of Hokkaido, Hokkaido, Japan, 14-15 June.

19) Uemura, T. and Mourato, S. (2008b) Jinkou gensho ka no syakaishihon kanri to jIzokukanousei (What is sustainability of infrastructure management in the context of population decline?). Paper presented at the 37th Conference of the Infrastructure Planning Committee, Japan Society of Civil Engineers, University of Hokkaido, Hokkaido, Japan, 14-15 June.

20) Uemura, T., Uto, M., Asami, Y. and Mourato, S. (2008c) Jinkou gensho chiiki niokeru jinkou gensho ga motarasu shakaishihonn heno gutaiteki na eikyo (Identification of actual impacts of population decline on infrastructure management in depopulated regions: Case studies in Hokkaido, Japan). Paper presented at the 11th Conference of Japan Association for Planning Administration, University of Tokyo, Tokyo, 20-21 September.

21) Uemura, T., Uto, M., Mourato, S., Asami, Y., Kobayashi, Y. and Matsuoka, M. (2008d) Yuso chosa niyoru jinkou gensho ga shakaishionkanri ni ataeru eikyo (Actual situations of impacts of population decline on infrastructure management mainly from engineering perspectives with extended PSR model (PSPCR model) in depopulated municipalities in Japan by a mail survey). Paper presented at the 38th Conference of the Infrastructure Planning Committee, Japan Society of Civil Engineers, University of Wakayama, Wakayama, Japan, 1-3 November.

22) Uemura, T., Mourato, S. and Uto, M. (2009) Analysing the environmental impact caused by population decline on infrastructure management: A case study of Japan, EAERE conference paper, now submitting.