JICA Research Institute

JICA-RI Working Paper

Research on Demand Estimate on Infrastructure in Asia

Estimating Social Infrastructure Demand: The Case of Japan

Fumiaki Ishizuka, Tsuyoshi Hara, Yu Namba, and Koki Hirota

No. 191

March 2019

JICA Research Institute

JICA Research Institute

JICA Research Institute
10-5 Ichigaya Honmura-cho
Shinjuku-ku
Tokyo 162-8433 JAPAN
TEL: +81-3-3269-3374
FAX: +81-3-3269-2054

Estimating Social Infrastructure Demand: The Case of Japan*

Fumiaki Ishizuka†, Tsuyoshi Hara‡, Yu Namba§, and Koki Hirota**

Abstract

The authors estimate the demand for social infrastructure investment (schools, health facilities, public housing, and government buildings) in Japan. These estimates include new construction, operation and maintenance (O&M), rehabilitation, and replacement, for the period from 2016 to 2030. Two approaches were applied to estimate the necessary infrastructure stock for each year: the multiplication of the projected number of beneficiaries by an infrastructure development standard (the micro approach) and a regression analysis with time-series data on socioeconomic variables (the macro approach). The demand for rehabilitation and replacement is examined carefully by using two alternative methods of estimation, an approach that is unique to this paper, having never been seen in other literature in this research field. The results indicate that the country needs to invest 10.3-13.5 trillion Japanese Yen or 94.6-124.0 billion USD†† in 2016 prices annually in the coming fifteen years to sustain the present level of social infrastructure services, an amount which is far larger than the current level of infrastructure investment. It also shows that the amount of spending related to O&M, rehabilitation and replacement is quite substantial, even though the required stock of social infrastructure will be smaller due to population decrease in the future. These findings and methodologies provide useful implications for a social infrastructure demand estimate for other Asian countries.

Keywords: Hospital, Housing, Infrastructure Investment Demand, Operation and Maintenance, School, Social Infrastructure.

---

* This paper has been prepared as part of a JICA Research Institute project entitled "Research on Demand Estimate on Infrastructure in Asia." This research is conducted as a first step to estimate social infrastructure demand in Asia. Based on the findings of this research, the authors plan to expand their study to other Asian countries.

† Deputy Director of the Southeast Asia and Pacific Department of the Japan International Cooperation Agency (JICA), ishizuka.fumiaki@jica.go.jp.
‡ Ph.D. Student at Reubin O'D Askew School of Public Administration and Policy, Florida State University, th17h@my.fsu.edu.
§ Associate Professor of Toyo University, yu-namba@toyo.jp.
** Professor at Saitama University, and JICA Research Institute, khirota@mail.saitama-u.ac.jp.

The authors would like to thank Yuji NEMOTO and Kazuyasu KAWASAKI for their valuable comments in the study meetings on this research project held in Toyo University. This paper also considerably benefited from comments by Toru TAKEMOTO who served as discussant at the Annual Meeting of the Japan Association of Applied Economics in June 2018.

†† 1USD = 108.84JPY, the average of monthly dollar/yen exchange rates in 2016 from the Bank of Japan, https://www.stat-search.boj.or.jp/index_en.html, is applied.

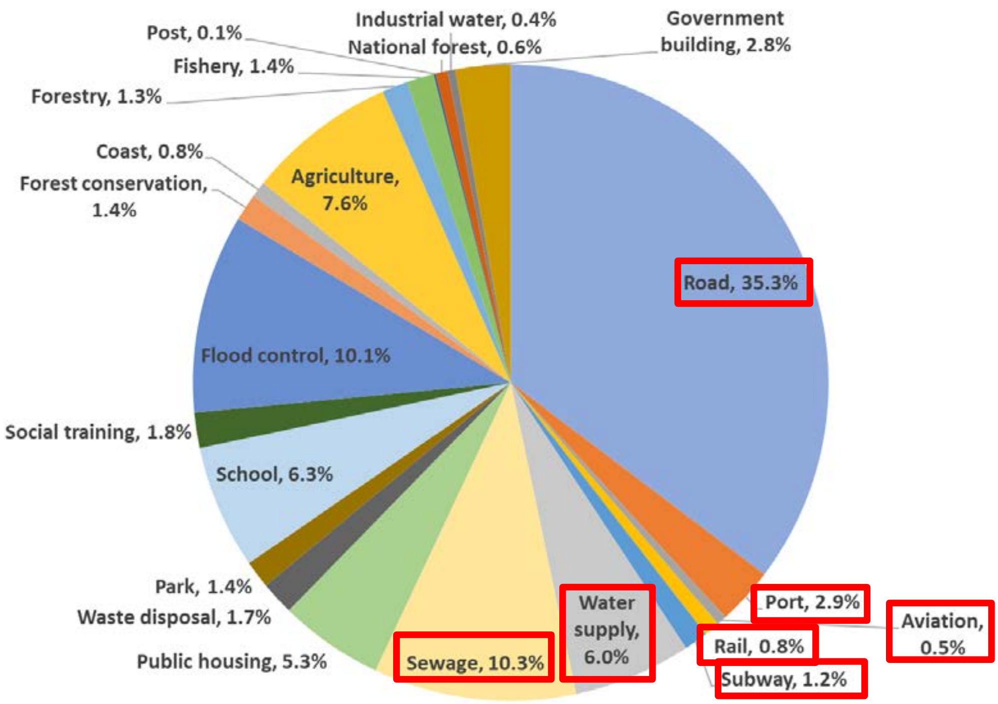
1. Introduction

The acceleration of economic growth in emerging countries has led to a rapid increase in demand for infrastructure in those countries. Asian countries are expected to continue to contribute more than 60% of global growth over the coming years, so that infrastructure demand in Asia will continue to be extremely strong well into the future. The Asian Development Bank (ADB) (2017) estimates that between 2016 and 2030, infrastructure demand will amount to 22.6 trillion USD in 2015 prices for the 45 countries of Asia, or 26 trillion USD if additional investment for mitigation and adaptation to climate change is included.

However, these figures only cover infrastructure demands in four economic sectors: power, transport, telecommunication, and water and sanitation (hereinafter collectively termed "economic infrastructure"), while the infrastructure demand of other sectors is also substantial. These sectors include education, rental housing for the low income (public housing), government buildings, disaster prevention (flood control and forest conservation), agriculture, and forestry and fisheries. According to the Cabinet Office of Japan (2017a), the four economic sectors represent only 57% of the country's public capital stock in value, as shown in Figure 1.[1]

[1] The public capital stock does not include much of the investment in the power, rail, telecommunication and health sectors because this is basically provided and operated by private sector in this country.

Figure 1: Japan's public capital stock by sector (Fiscal Year 2014)



Source: Cabinet Office of Japan (2017a)

In particular, social infrastructure such as schools, health facilities, public housing and government buildings (hereinafter grouped as "social infrastructure") is not part of the discussion in many cases. However, it cannot be ignored. The role of social capital is increasingly important for long-term growth in emerging countries and is integral to the attainment of the Sustainable Development Goals (SDGs). In Asia, where many countries have entered the middle-income stage of development, human resources, which cannot be realized without the proper development of social infrastructure, are considered a key in overcoming the impact of the so-called "middle-income trap."

In Japan, social infrastructure investment, which is rarely recovered by operational revenues is considerably challenging at this moment when the financial deficit is expanding due to increasing social security expenditure on the aged population. It is not financially viable to recover the development cost of social infrastructure through operational revenue, unlike economic infrastructure which is expected to generate revenue to recover development costs by itself. Moreover, social infrastructure requires long-term spending for operation and maintenance (O&M), rehabilitation and replacement to sustain the level of social services already provided.

Against this background, the authors sought to estimate social infrastructure demand in the whole Asian region. However, since estimating regional social infrastructure demand is an unprecedented exercise, we needed to begin with the establishment of a new methodology for the demand estimate. We thus conducted a country case study for Japan as an initial exercise to examine an appropriate methodology that may be applied to other Asian countries at a later stage.

This paper sets out to estimate the demand of social infrastructure in Japan. This includes including new construction, O&M, and rehabilitation and replacement from 2016 to 2030, the target period for the SDGs. We use two different approaches to estimate the necessary infrastructure stock for each year, namely the micro and macro approach. We also discuss the significance of the estimated figures of demand by comparing them with the current level of investment. We then discuss some implications of the methodology and results of the demand estimate in view of our intention to extend this exercise to other Asian countries.

The contribution of this research can be summarized as follows. First, this is an initial attempt at social infrastructure demand estimate by projecting future necessary stock volumes that vary with changes in other socioeconomic factors. The authors try to unravel the mechanism through which social infrastructure stock is defined by demography, urbanization, economic development and other factors. Second, this is a first effort to estimate holistic social infrastructure demand by covering the whole lifecycle of social infrastructure, including O&M, rehabilitation, and replacement. Through this exercise, the authors highlight the significance of the long-term financial burden to the country in sustaining the current level of social services over the coming decades.

2. Literature

Infrastructure demand estimates on an international scale have been conducted in several literatures. The most frequently quoted study is Fay and Yepes (2003), which covered the economic sectors of infrastructure: power, transport, telecommunications, and water and sanitation. It is a macro approach in which they used regression analysis to estimate the necessary infrastructure stock for each year based on the following equation:

$$I_{i,t} = \alpha_0 + \alpha_1 I_{i,t-1} + \alpha_2 y_{i,t} + \alpha_3 A_{i,t} + \alpha_4 M_{i,t} + \alpha_5 D_i + \alpha_6 D_t + \epsilon_{i,t}$$

Where: $I_{i,t}$ denotes infrastructure stock in Country i and Year t; y is income per capita; A is the share of agriculture in GDP; M is the share of manufacturing in GDP; D_i is the country fixed effect, D_t is a time dummy, and ε is an error term. They also considered urbanization ratio and population density as explanatory variables as they allow easier and cheaper access to infrastructure goods provided through networks.

In this equation, it is assumed that the **demand for** economic infrastructure derives from consumption by both the household and production sectors. For example, electricity demand is the sum of the power consumption of both the household and production sectors, including factories and office buildings. Based on this, our explanatory variables were chosen as follows:

1) Household demand = f (Y, qI)

   Y: income

   qI: infrastructure service price

2) Production sector demand = f (Y, qI, Yag, Yind, A)

Yag: agriculture’s share of GDP

Yind: industry’s share of GDP

A: technology, based on the Cobb-Douglas production function

In addition to the demand for new construction, demand for operation and maintenance (O&M) is estimated by multiplying the existing infrastructure stock by a certain proportion such as 2 percent for power and transport, 3 percent for water and sanitation, and 8 percent for telecommunications. Demand for rehabilitation and replacement is not explicitly considered and distinguished in this estimation.

Besides Fay and Yepes (2003), a certain number of demand estimates for new construction and O&M of economic infrastructure have been conducted on a global and regional scale. The most recent and comprehensive study is one by the ADB (2017), which covers economic infrastructure for the 2016-2030 period. This study used a regression analysis model with some modifications. There are also studies that have conducted demand estimates for economic infrastructure.[2]

However, to the best of our knowledge there has been no study so far that has focused on the new construction and O&M of social infrastructure on either the global or regional scale.[3] As the nature of social infrastructure is different from economic infrastructure, its demand is basically not derived from a productive sector. The authors have observed in this context that the explanatory factors in the regression models used may not be suited to social infrastructure demand estimates. For instance, the demand for primary school facilities is exclusively influenced by the number of students, because primary education is obligatory for all children at

[2] There are other methods of economic infrastructure demand estimate: Foster and Briceno-Gamendia (2010) conducted individual sector analysis on potential pipeline projects to meet the future power demand derived from the growth model in Africa; Fay and Morrison (2007) estimated the amount to bridge the gap of economic infrastructure stock between the current level of target countries in Latin America and the level of Korea used as a benchmark.

[3] Unlike economic infrastructure, social infrastructure, particularly education and health, can only be made available when there is enough qualified personnel. The volume of education and health facilities is subject to the availability of these experts. Aside from these numbers, the skills of experts are crucial for the outcome of such social services. However, in this paper we did not consider the availability, limitation or quality of those experts, as this would require another set of analyses.

the target age, regardless of the income level of the family. The rare exception may be those parts of the higher education sector that are influenced by changes in labor demand due to industrial development.

Nonetheless, there are several studies on the social infrastructure demand estimate at the country level from Japan, where the investment to replace deteriorating infrastructure is a social challenge. Nemoto (2017) estimated the annual demand for the replacement of school, public housing (rental housing for low-income), and government building. He estimated annual volume of infrastructure to be replaced using the division of the year's infrastructure stock by the fixed service life of each infrastructural item. For primary and junior high school, the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) (2013) estimated the volume of facilities to be rehabilitated and replaced for the 2012-2041 period based on the actual record of school construction since 1949. This study first estimated the annual volume of infrastructure to be replaced or rehabilitated and then multiplied those estimates by construction unit prices to obtain the necessary amount of investment.

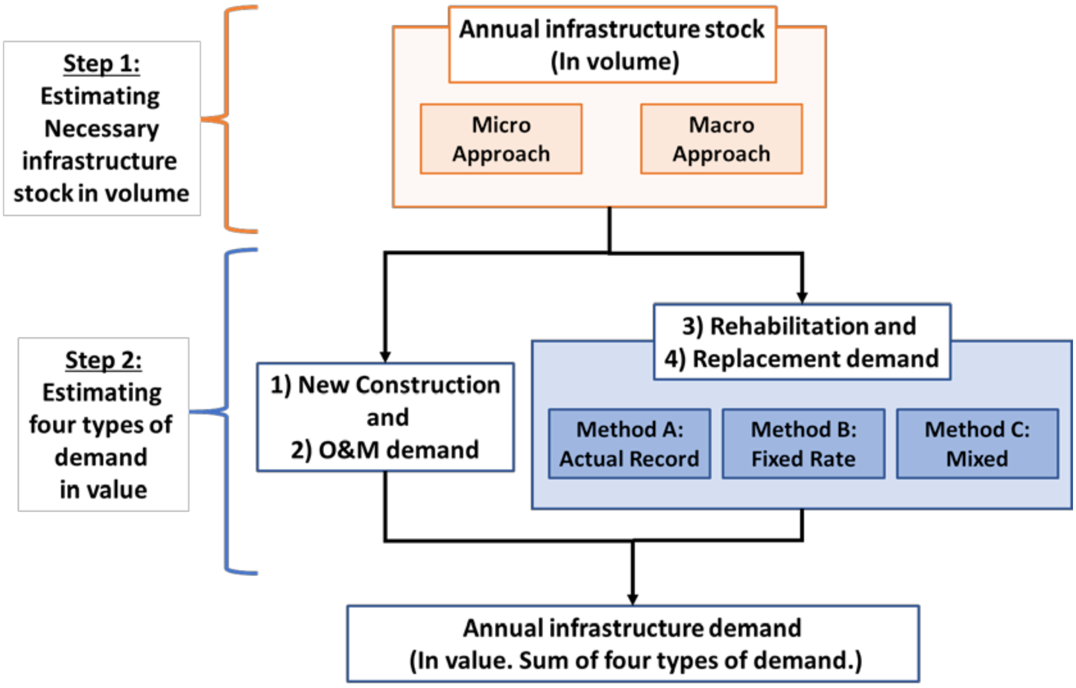
While the previous literature has revealed the amount of demand based on the estimated stock volume (the number or floor area of existing infrastructure) of the necessary infrastructure, there is another approach that could be used to generate demand estimates: a direct calculation of the necessary investment amount without calculating the infrastructure stock volume. Akai and Takemoto (2015) applied this methodology for the road sector in Japan. They used the past annual investment amount data from the System of National Accounts (SNA) to estimate the stock in value of road infrastructure during 1956-2012, and generated the necessary amount of replacement investment until 2040.

3. The Model

Based on the literature review, the authors developed a methodology to estimate investment demand across the lifecycle of social infrastructure: new construction, O&M, rehabilitation, and replacement. It covers the 2016-2030 period and four sectors of social infrastructure: schools (kindergarten, elementary school, junior high school, high school, university and junior college), health facilities (hospital, clinic and health facility for the aged), public housing (public rental housing for the low-income), and government buildings (office building of central and local government).

The authors do not directly estimate the demand *in value* (in monetary terms), we first estimate the necessary infrastructure stock *in volume* for each year (Step 1) and then use this estimation of volume to obtain the necessary investment amount for new construction, O&M, rehabilitation, and replacement (Step 2). As the unit price for O&M and rehabilitation is different from that for new construction and replacement, it is necessary to separately produce the stock volume as a basis for the calculation of different types of demand at a later stage. Moreover, in Step 2, rehabilitation and replacement demand are estimated separately from new construction and O&M demand because the calculation method of rehabilitation and replacement demand differs according to the availability of the data on the past record of infrastructure investment.

Figure 2: Overview of the model for social infrastructure demand estimate



Source: Authors

We breakdown the life-time cost as O&M, rehabilitation, and replacement, which is the first attempt to do that. Replacement, complete reconstruction, only happens at the end of life of a facility, therefore if we know the construction year, we can simply put the initial construction amount at the end (we do not consider the cost for removal). If we do not know the construction year, we can allocate a certain ratio of the facility value throughout the operating years, which is same as the depreciation concept. On the other hand, the objective of rehabilitation is to keep the facility condition appropriate through change or large repair of interior decoration or electrical and mechanical equipment, which cannot be covered by daily operation and maintenance. While it may happen from time to time throughout the operating years (it is assumed that in our model that it becomes necessary once at the middle of a facilities lifetime), its nature is basically the same with an extension of maintenance in terms of maintaining the quality of infrastructure until the end of its lifetime. If we know when the rehabilitation will occur during the operating years, we can allocate a certain amount for rehabilitation in that year. If this is uncertain, we may allocate a certain ratio of the facility value throughout the operating years, however the nature of this action is different from depreciation. Finally, O&M is defined as daily operation and maintenance, including cleaning, security, inspection, utility and minor repair that occurs regularly throughout the operating years, therefore we simply allocate a certain ratio of the facility value throughout the operating years.

Step 1: Estimating necessary infrastructure stock in volume

To determine the methodology to estimate the necessary stock in volume for each year of the target period, the authors conducted two different approaches: multiplication of the projected number of beneficiaries by an infrastructure development standard (the micro approach) and a regression analysis with time-series data on socioeconomic variables (the macro approach). The features of the two approaches are summarized in Table 1.

Table 1: The overview and features of the micro and macro approaches

		Overview	Features
The micro approach		Multiplication of the projected number of beneficiaries (the number of school-age population) by an infrastructure development standard (the number of schools or floor area of school per student)	- The demand can be estimated without considering constraints on the supply side such as government budget ceilings or construction industry capacity. - Estimates can be conducted, even when the time-series data on past infrastructure stock is not available.
The macro approach		Regression analysis with time-series data on socioeconomic variables (the number of schools, population at target age, GDP per capita, urbanization rate)	- As the analysis is based on time-series data about past infrastructure stock (the result of supply-demand equilibrium), the potential needs of the demand side may not be considered

Source: Authors

For the micro approach, each year's infrastructure stock in volume as measured by the number or floor area of facilities is estimated by multiplying the projected number of beneficiaries by an infrastructure development standard. The projected number of beneficiaries can be obtained by the multiplication of the projected future population at target age (population at the age of 6 to 12 for elementary schools) by the projected rate of usage of the facility (e.g. school enrollment rate for school facility). The infrastructure development standard is an official regulation or general norm that is commonly used by public administrators for the purpose of securing the level of social infrastructure services (necessary floor area per student for school facility or necessary number of clinics per head of population).

For the macro approach, the number of facilities is estimated by regression analysis, using time-series data on past infrastructure stock as measured by the number of facilities (dependent variable) and socioeconomic factors such as population at target age, GDP per capita and urbanization rate (independent variables). The agriculture and manufacturing sectors' share of GDP, the variables used in Fay and Yepes (2003) for economic infrastructure, was not used in this analysis because the authors assumed that the stock of social infrastructure is not influenced by the demands of the production sector, as mentioned above. In our regression equation, the intention was to obtain the best fit possible and the highest explanatory power. We thus included the lagged value of the dependent variable in the regression to increase explanatory power. The lag length for each regression formula was selected by means of information criteria such as the Akaike Information Criterion (AIC) and the Bayes Information Criterion (BIC).

In the macro approach, the estimate was conducted only for the education and health sectors due to the constraint of data availability: reliable time-series data on the infrastructure stock volume (the independent variable) for various time periods could not be obtained for public housing and government buildings.

The equation for education facilities is shown in Equation 1:

$$\mathrm{I}_{\ t} = \alpha_0 + \alpha_1(\mathrm{I}_{\ t-i}) + \alpha_2 y_t + \alpha_3 \mathrm{Urban}_t + \alpha_4 \mathrm{pop}_t^j + \epsilon_t \ \cdots \qquad 1$$

Where: all variables are in natural logs to linearize the model; $\mathrm{I}_{\ t}$ is demand for infrastructure stock at time t; $(\mathrm{I}_{\ t-i})$ is the lagged value of the infrastructure stock; y_t is income per capita; Urban_t is the urbanization rate; pop_t^j is the population of target age j for each facility (population from 3 to 5 years old for preschool education facility (kindergarten), population from 6 to 14 for early secondary education facility (junior high school), population from 15 to 17 for late secondary education facility (high school) and population from 18 to 21 for higher education facility (university and junior college)); and ϵ_t is an error term.

Income per capita leads to an increase in the number of educational facilities since the enrollment rate and/or the size of infrastructure may increase following improvements in income level. The progress of urbanization is also assumed to be a variable that may have an influence on the number of education facilities through easier access by beneficiaries. Note that this urbanization rate expresses the density of facilities and is not a proxy for service price as Fay and Yepes (2003) introduced in their estimates of economic infrastructure.

The relationship for health facilities is shown in Equation 2. Note that, in the case of hospitals, the number of beds is adopted as a dependent variable, instead of the number of facilities:

$$\mathrm{I}_{\ t} = \alpha_0 + \alpha_1(\mathrm{I}_{\ t-i}) + \alpha_2 y_t + \alpha_3 \mathrm{Urban}_t + \alpha_4 \mathrm{Pop}_t + \alpha_5 \mathrm{Eld}_t + \epsilon_t \ \cdots \qquad 2$$

Where: all variables are in natural logs to linearize the model; $\mathrm{I}_{\ t}$ is demand for infrastructure stock at time t; $(\mathrm{I}_{\ t-i})$ is the lagged value of the infrastructure stock; y_t is income per capita; Urban_t is the urbanization rate; Pop_t is the population of all age; Eld_t is elderly rate; and ϵ_t is an error term.

Higher income per capita leads to an increase in the number of health facilities through improvement in users' ability to pay for medical expenses. In addition, the progress of urbanization may lead to easier access for beneficiaries to hospitals and clinics and encourage changes in the number of facilities. The authors did not set any proxy of service price because while universal health care was introduced in Japan in 1961, the time-series data on the variables have been available only since 1955. Moreover, since the number of beds in hospitals and the number of clinics may be affected by the demography, the population of all ages and the rate of elderly, who may be more likely to need medical treatment, were adopted as independent variables.

Step 2: Estimating four types of demand in value

Once the estimated necessary stock in volume is obtained by the micro or macro approach, four types of annual social infrastructure demand in value can be obtained by applying different equations. Those four demand types are: 1) new construction demand; 2) O&M demand; 3) rehabilitation demand; and 4) replacement demand. The sum of those four types of annual demand equals the demand from the social infrastructure for each year.

1) New construction demand is obtained by the following equation:

Annual new construction demand = Construction unit price x Increase in the necessary infrastructure stock volume in the year of estimate

In the case that the necessary infrastructure stock in volume decreases from the previous year, the demand turns out to be zero.

2) O&M demand is obtained by the following equation:

Annual O&M demand= O&M unit price x Estimated necessary infrastructure stock volume in the year of estimate

O&M unit price is the standard annual cost for O&M operations of facility, such as cleaning, security, and minor repairs that are not regarded as capital investment.

3) Rehabilitation demand can be theoretically estimated as follows by three different methods according to the availability of time-series data on the past infrastructure stock in volume. The visual depiction of those three methods is shown in Annex 1.

Method A: Actual Record

In the case where time-series data on the actual volume of infrastructure stock is fully available, it is possible to grasp the timing and amount of rehabilitation of the facility. For example, if the data shows that 50 units of infrastructure have been constructed every year for the period from year t-20 to year t and that the actual stock volume reaches 1000 units in year t from zero in year t-20, it is obvious that the volume of infrastructure constructed in year t is 50 units. In this case, the volume of infrastructure to be rehabilitated in year t+30 is also 50 units, because rehabilitation occurs 30 years after construction or at the middle of its lifetime (60 years) to maintain the quality of infrastructure until the end of its lifetime.[4] Then we can calculate the value by multiplying this volume by the unit cost of rehabilitation.

Method B: Fixed rate

When data is not available at all, the rehabilitation demand can be estimated by the division of each year's estimated necessary stock volume by the lifetime of this form of infrastructure, under the assumption that an equal amount of infrastructure has been constructed every year in the previous 60 years. For instance, if the estimated necessary stock volume is 1000 units in year t+30, the volume of infrastructure rehabilitated in year t+30 turns out to be 1.67 percent of 1000

[4] In this paper, rehabilitation is defined as necessary investment in the middle of its lifetime, 30 years after the new construction of the facility, to maintain the quality of service derived from social infrastructure until the end of its lifetime.

units, which is the ratio divided by 60 (the period of infrastructure life time). Then we can calculate the value by multiplying the unit cost for rehabilitation.

Method C: Mixed

When the required data can be traced back to some extent but is not fully available, both methods can be used together. Method A can be applied for the facilities constructed after the oldest year in which the data is available, while Method B can be applied for the ones in and before that year. Note that, for the latter, the division by the lifetime of infrastructure is applied not for each year's estimated necessary stock volume but for the actual stock volume of the oldest year in which the data are available. For example, if the data are available only since year t-10 and if the data shows that the actual stock volume in the year is 500 units and that 50 units of infrastructure has been added every year for the period from year t-10 to year t, the volume of infrastructure constructed after year t-10 and supposed to be rehabilitated in year t+30 is also 50 units, as shown in the example using Method A. On the other hand, the volume of infrastructure constructed in and before year t-10 and supposed to be rehabilitated in year t+30 is 1.67 percent of 500 units, because we assume that the same amount of infrastructure had been constructed every year in the previous 60 years of year t-10, as shown in the example used to illustrate Method B. Thus, the volume of infrastructure that is supposed to be rehabilitated in year t+30 turns out to be the sum of 50 units plus 1.67 percent of 500 units. Then we can calculate the value by multiplying the unit cost for rehabilitation.

In addition, the decrease in the estimated necessary stock volume of infrastructure, derived from the decrease in the number of beneficiaries or changes in other variables, is reflected as follows: in Methods A and C, the amount of annual decrease in the stock volume is directly subtracted from the calculated volume of requiring rehabilitation. On the other hand, this point is already considered in Method B, where the division of each year's necessary stock volume by the service life of infrastructure is calculated. When the necessary stock volume decreases, the calculated volume of rehabilitation also decreases accordingly. In either case, it is assumed that, in the phase when the necessary stock volume is declining and the infrastructure in the middle of its service life is showing deterioration in interior decoration and electrical and mechanical equipment, this does not need to be fully rehabilitated for use for another 30 years. Based on the above-mentioned concept, the equations for those three methods are indicated in Table 2.

Table 2: Equation of three methods of rehabilitation demand estimate

Method	Equation
Method A: Actual Record	Annual rehabilitation demand = Rehabilitation unit price × (Annual increase in infrastructure stock volume 30 years ago - Annual decrease in infrastructure stock volume in the year of estimate)
Method B: Fixed Rate	Annual rehabilitation demand = Rehabilitation unit price × Estimated necessary infrastructure stock volume in the year of estimate ÷ Facility lifetime
Method C: Mixed Method	Annual rehabilitation demand = Rehabilitation unit price × (The volume of infrastructure that is supposed to be rehabilitated* - Annual decrease in necessary stock volume in the year of estimate) * The volume of infrastructure that is supposed to be rehabilitated: = Annual increase in infrastructure stock volume 30 years ago + Actual infrastructure stock volume in the oldest year for which the data on the past infrastructure stock volume is available ÷ Facility lifetime

Source: Authors

The authors applied B and C for the demand estimates in this paper. In reality, it was not possible to apply Method A in the context of Japan because this method requires a full dataset on the infrastructure stock volume from the origin of social infrastructure, and the required data from back in the *Meiji* restoration era was not available. It is noted that Method C is more complex than Method B and contains a discontinuity of applied methodology between the years in and before and the years after the oldest year with data available. On the other hand, the results of this method may better reflect the actual timing of rehabilitation and replacement of infrastructure because the analysis is still partially based on the past record of actual infrastructure development.

4) Replacement demand can be estimated in the same way as rehabilitation demand depending on the availability of time-series data on past infrastructure stock volumes. The equations are shown in Table 3.

Table 3: Equation of three methods of replacement demand estimate

Method	Equation
Method A: Actual Record	Annual replacement demand = Replacement unit price × (Annual increase in infrastructure stock volume 60 years ago - Annual decrease in infrastructure stock volume in the year of estimate)
Method B: Fixed Rate	Annual replacement demand = Replacement unit price × Estimated necessary infrastructure stock volume in the year of estimate ÷ Facility lifetime
Method C: Mixed Method	Annual replacement demand = Replacement unit price × (The volume of infrastructure that is supposed to be rehabilitated* - Annual decrease in infrastructure stock volume in the year of estimate) * The volume of infrastructure that is supposed to be rehabilitated = Annual increase in infrastructure stock volume 60 years ago + Actual infrastructure stock volume in the oldest year in which the data on the past infrastructure stock volume is available ÷ Facility lifetime

Source: Authors

4. Data

<u>Step 1: Estimating necessary infrastructure stock in volume</u>

For <u>the micro approach</u> to estimating necessary infrastructure stock volume, most of the necessary data was obtained from the official statistics of the Japanese government. The approach required multiplication of the projected number of beneficiaries by an infrastructure development standard. The projected number of beneficiaries equals projected population times a facility usage rate for education and health. For public housing and government building, other factors (separation of household, headship rate, income level, area of administrative jurisdiction) are also taken into consideration in the estimation. The sources of these data are summarized in Table 4.

Table 4: Data sources for the micro approach

Data		Sources
Population projection		An official population projection by age group is available from the National Institute of Population and Social Security Research (2013)
Facility usage rate	Education	School enrolment rates in the target period (2016-2030) are assumed to be an average of the rate in recent years, available from the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) (2015a), because the rate has been stable and has rarely changed in recent years
	Health	The ratio of outpatient and inpatient per population by age group in the target period (2016-2030) is projected by linearly extending the past 15-year trend of the ratio available from the Ministry of Health, Labour and Welfare (MHLW) (2013) and MHLW (2014a)
	Public housing	The number of households eligible for low-income public housing (that live in rental housing and cannot afford minimum floor area housing in the market) is calculated with the guidance provided by Ministry of Land, Infrastructure, Transport and Tourism, using housing and census data available from the Ministry of Internal Affairs and Communication (MIC) (2003, 2008, 2013) and MIC (2005, 2010, 2015)[5]

[5] More specifically, the number of households eligible for low-income public housing is obtained by the following three steps:

1. Estimate the number of households:

	Government building	The Number of personnel and elected officials (prefectural and municipal) calculated using Personnel capacity regression (population, land area, area of habitable land, classification of local government), and floor area is calculated using the old standard for national grants to local governments. Necessary data were retrieved from MIC (2011), MIC (2015a), MIC (2015b), MIC (2016), National Association Chairmen of Town and Village Assemblies (2017), and National Association of Chairpersons of City Councils (2015). For the central government, the number of officials is available in Cabinet Secretariat (2015), and change is according to population change
Infrastructure development standard	Education	A standard on the necessary floor area per student for the purpose of calculating the amount of subsidy from central to local government is available in MEXT (2015b) and MEXT (2015c)
	Health	The necessary floor area per patient is obtained by the multiplication of an average floor area per facility and the number of facilities per patient. The former is calculated for those facilities registered in the database of Japan Institute of Healthcare Architecture (2017). The latter is available in MHLW (2013) and MHLW (2014b)
	Public housing	Standard floor area for each low-income housing unit including communal/service area was calculated based on MLIT (2016). While the minimum floor area standard varies by household size, a fixed floor area is applied in the estimation. Floor area includes not only the floor area for the exclusive use for each household, but also the common-use area space

---

Using Population projection, trends in actual population change and number of households, and headship rate, estimate future headship rate to calculate estimated number of household (by gender and five-year age group of household head and family type*) in the future.
* Family type: Single or Multiple (conjugal couple/parents and children/single parent and children/others)

2. Estimate of households that are not affordable of proper housing and eligible for public housing:
1) Estimate of ratio of households in each income group (quintile) using actual data from income group, household size and house ownership, estimate the ratio of households by income group, household size and house ownership, and given the result of estimate 1, calculate the ratio of households in each income group (quintile);
2) Estimate of number of target household that are eligible for public housing. The target income groups are single elderly households and households with children under six years old; and
3) Target households that cannot afford proper housing and are eligible for public housing using estimate of private rent in the region by square meter gives an estimate of target households that cannot afford housing in the private market.

3. Decide the volume of public housing that is needed to meet the demand
“Households that cannot afford proper housing and are eligible for public housing” is not necessarily the stock od public housing that the government should provide. Therefore, the estimation is adjusted in line with actual housing stock. An alternative method (not used in this paper) is the estimation (results of step 2) multiplied by the ratio of households living under minimal standards (housing size and inadequate facilities—no independent toilet in each housing unit, and so on).

	Government buildings	For central government's administrative buildings, MLIT (2017c) is referred to in the calculation of necessary floor area. In addition, MIC (2010) is widely used among local governments though it is no longer considered an official standard. Local governments often refer to and combine both MIC and MLIT standards. MLIT's standard was used for the central government data and the MIC standard was used for local government data. In addition, about 70 municipalities are referred to for their actual consideration of floor area in recent redevelopment projects to make some assumptions on the necessary function and floor area in local governments.

Source: Authors

For the macro approach to estimating the necessary infrastructure stock, time-series data from 1960 to 2015 on the number of each type of education facility was used as dependent valuable. For health facilities, time-series data from 1975 to 2014 on the number of health facilities was used. The figures of independent variables are calculated as follows: first, this paper used linearly interpolated data for each age group in the population up to 2030, based on forecast data published by the National Institute of Population and Social Security Research (2013). Second, the projection of GDP was calculated from the annual GDP growth rate published by the OECD (2017). Finally, the annual increase rate of urbanization from 2014 to 2015 from United Nations (2014) was extrapolated to 2030.

Step 2: Estimating four types of demand in value

Once the necessary infrastructure stock volume is estimated, the four types of demand in value can be accordingly estimated. The sources of data used in this phase are summarized in Table 5. For the actual record of past infrastructure stock (and annual flow) in volume of construction, more detailed information on the availability of data is summarized in Annex 2 for reference, as well as the data on actual record of past annual infrastructure investment in value.

Table 5: Data sources for the estimate of the four types of demand

Data		Sources
Construction unit price	New construction	The construction unit price commonly used by local governments is available at Japan Foundation for Regional Vitalization (2016)
	O&M	The annual O&M unit price applied in this paper is 1 percent of the construction unit price. The ratio of O&M cost to construction cost is available from the Building Maintenance and Management Center (2005)
	Rehabilitation	The rehabilitation unit price applied in this paper is 60% of the construction unit price, under the assumption that the construction cost of a public building can be divided into four categories (30% for building structure, 30% for electrical and mechanical equipment, 30% for interior decoration, and 10% for others) and that only the change of equipment and interior decoration is regarded as necessary capital investment at the middle of the infrastructure's service life cycle to maintain the quality of infrastructure
	Replacement	The same amount as new construction is applied
Facility lifetime		The lifetime of social infrastructure is assumed to be 60 years following the Japan Foundation for Regional Vitalization (2016), which is a standard commonly used by local government for the purpose of estimating the replacement cost of infrastructure
Actual record on past infrastructure stock volume	Education	Data on the number of facilities constructed since 1960 is available from MEXT (2015a)
	Health	Data on the number of clinics constructed since 1955 and the number of beds for hospital and facilities for the aged since 1975 is available from MHLW (2014b)
	Public housing	The number of public low-income housing facilities construction since 1978 (every five years) is available from MIC (2013)
	Government building	National and local government building data is available since 2009 and 2005 respectively from MLIT (2017a). Because the available published data is relatively recent, we only used current (2015) stock data in the method C estimate

Source: Authors

5. Results

Result of infrastructure demand estimates

The results of the demand estimates are in Table 6 and 7, respectively for the result when the micro approach for necessary stock volume estimate is applied and for the result when the macro approach is applied. All the amount of estimate result described in the following tables are assumed to be in 2016 prices because the unit prices used in the estimate is quoted from a common standard for the local governments published in 2016 (Japan Foundation for Regional Vitalization (2016)), while the source does not specify the base-year of each unit prices.

Table 6: Estimate Result in case of the micro approach applied

Unit: million Japanese Yen in 2016 prices

	Total of four types of demand *Method B (Fixed rate) applied for rehabilitation and replacement demand		Total of four types of demand *Method C (Mixed) applied for rehabilitation and replacement demand	
	Annual average	in % of projected annual GDP	Annual average	in % of projected annual GDP
Education	4,065,824	0.71%	3,241,257	0.57%
Health	6,863,199	1.20%	4,911,145	0.86%
Public housing	1,907,093	0.33%	1,567,058	0.27%
Government building	681,587	0.12%	577,169	0.10%
Total	13,517,703	2.36%	10,296,630	1.80%

Source: Authors

Table 7: Estimate Result in case of the macro approach applied

Unit: million Japanese Yen in 2016 prices

	Total of four types of demand *Method B (Fixed rate) applied for rehabilitation and replacement demand		Total of four types of demand *Method C (Mixed) applied for rehabilitation and replacement demand	
	Annual average	in % of projected annual GDP	Annual average	in % of projected annual GDP
Education	3,660,656	0.64%	3,873,166	0.68%
Health	5,789,580	1.01%	4,936,085	0.86%
Total (*)	12,038,916	2.10%	10,953,478	1.91%

* The total of macro approach estimate includes the result of public housing and government building obtained by the micro approach.

Source: Authors

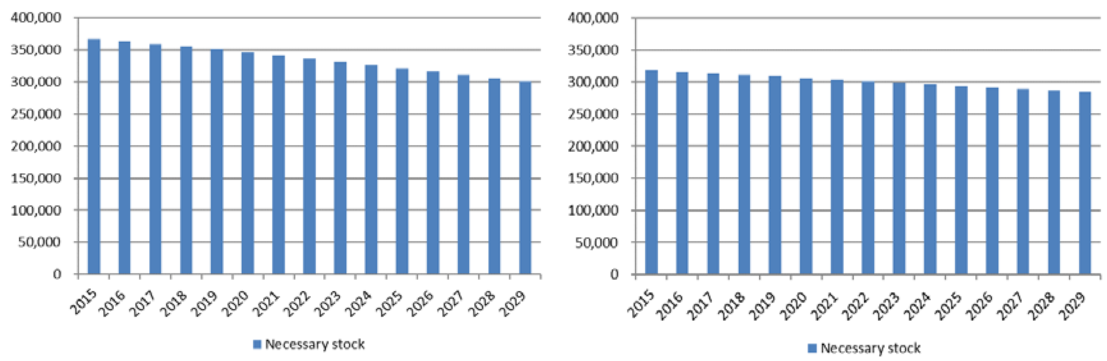
The result indicates that Japan's social infrastructure demand is 10.3-13.5 trillion Japanese yen or 94.6-124.0 billion USD[6] annually in average for the target period from 2016 to 2030. This figure equals to 1.8-2.4% of the annual GDP of the country. The figure from the method C (Mixed) seems generally smaller than the case of the Method B (Fixed rate), except for the case of education facility of the macro approach. This may be derived from the difference of rehabilitation and replacement demand between the past actual stock record (the method C) and the estimated necessary stock in the said period (the method B). Moreover, the figure from the micro estimate is larger than the one from the macro approach in the case of the method B, which is derived from the fact that the estimated necessary stock from the micro approach exceeds the figure from the macro approach as shown in the example of school (Figure 3) because the micro approach is free from the supply constraints. On the other hand, the estimated figure by the micro approach is smaller than the one by the macro approach in the case of the method C, because that the amount of the annual decrease in the necessary stock for the target period is generally larger in the micro approach than in the macro approach, as shown in Figure 3; the impact of the direct subtraction of this annual decrease from the volume to be rehabilitated or replaced is larger than the aforementioned difference of the nature of the two approaches on the supply constraints.

[6] 1USD = 108.84JPY, the average of monthly exchange rates in 2016 from the statistics of Bank of Japan retrieved at https://www.stat-search.boj.or.jp/index_en.html, is applied.

Figure 3: Estimated necessary stock volume (Example of education facilities)

Unit: Thousand square meters

1) Micro approach 2) Macro approach



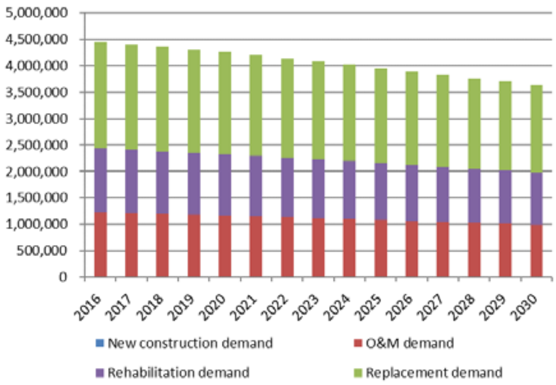
Source: Authors

The new construction demand rarely appears while a certain amount of O&M, rehabilitation and replacement is estimated, as shown in the example of education facilities (Figure 4). Since the population of Japan is decreasing and income per capita is relatively stable, the necessary infrastructure stock will gradually decrease, and new construction demand is barely observed in most cases of the estimated scenarios. On the other hand, the demand for O&M, rehabilitation and replacement is still significant because the volume of the current infrastructure stock accumulated so far is certainly large, which requires a continuous investment to maintain the quality of social services in the coming decades.

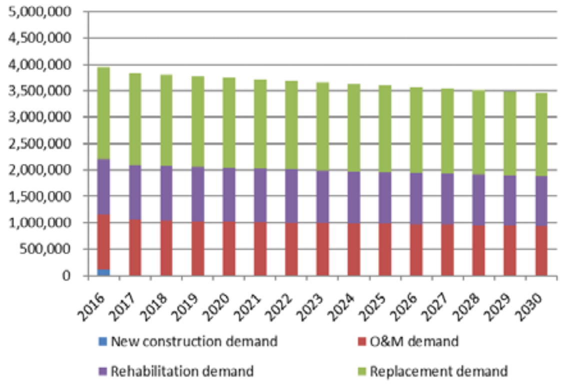
Figure 4: Breakdown of the estimated infrastructure demand by type (Example of education facilities)

Unit: million Japanese Yen in 2016 prices

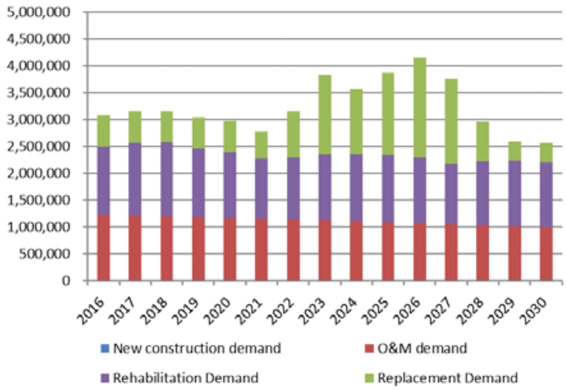
1) Micro approach with method B



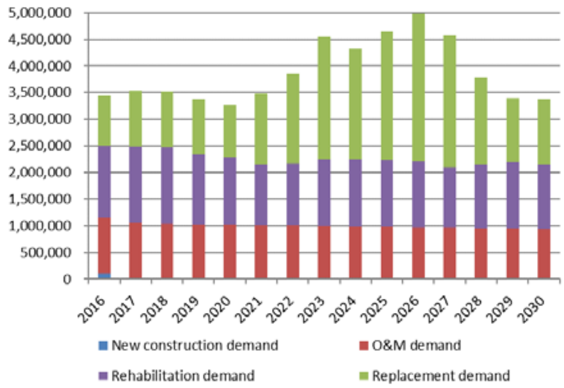
2) Macro approach with method B



3) Micro approach with method C



4) Macro approach with method C



Source: Authors

The results of the regression analysis of the macro approach is summarized in Annex 3. For education facilities, this indicates that population of target age has a positive influence on the infrastructure stock, as shown in the case of obligatory education facilities (elementary and junior high schools). GDP per capita has also a positive influence on the stock of higher education facilities (university and junior colleges), which implies that economic development requires more human resources with advanced skills.[7] The influence of urbanization is also

[7] It is puzzling that the influence of GDP per capita is negative on the stock volume of high schools as

positive in the case of high schools, while it is not statistically significant for other types of education facilities, indicating that urbanization or depopulation in rural areas has two-sided effects on the number of schools. For health facilities, the population in all age groups has a positive influence on the volume of hospital facilities (hospital beds), while it is negative and statistically less significant in the case of clinics. On the other hand, the number of clinics is significantly influenced by the progress of population aging. GDP per capita also has a positive influence on the volume of both hospitals and clinics. Urbanization rate has a negative impact on the number of hospitals and clinics, which implies that fewer health facilities are necessary if the urbanization progresses because the number of beneficiary served by one health facility increases.

Note that the estimated figures should be regarded as minimum boundary of social infrastructure demand. First, the figures are only for four social infrastructure sectors: school, health facilities, public housing and government building. The figure would become larger if other types of social infrastructure such as culture and sport facilities are added. Second, necessary costs of equipment that is supposed to be attached particularly to education and health facilities are not included in this estimate. Thirdly, as far as the micro approach is concerned, the estimated demand would further swell if the concept of number of room or facility was introduced. In the micro approach of this study, square meter was applied as unit of necessary stock estimate. However, there may be the case that the number of student in a particular grade of school is only a few but it require one classroom. In such cases, the difference in the estimated demand is created by the difference between theoretically necessary stock calculated using this estimate (the multiplication of a fixed development standard in square meters by the number of students) and *necessary* stock (one classroom).

---

shown in Annex 3. However, it turns out to be positive if the lagged dependent variable is excluded from the regression equation.

Comparison with actual infrastructure investment

A substantial gap was observed between estimated demand and the current level of infrastructure investment for schools, health facilities and public housing, as shown in Table 8. The estimated demand is two to three times larger than the current investment for schools, three to five times larger for health facilities, and one to two times larger for public housing. The demand for O&M, rehabilitation and replacement in the coming decades is significant as explained above. The observed substantial gap corresponds to the ongoing discussion in the country about the lack of financial resources for the rehabilitation and replacement of existing infrastructure.

Table 8: Comparison of estimated demand with the current annual investment and annual cost to sustain existing infrastructure stock

Unit: billion Japanese Yen in 2016 prices

Sector	Annual average of demand (new construction, rehabilitation and replacement demand only)				Current annual investment*		Annual cost to sustain existing volume of infrastructure stock
	Micro approach		Macro approach				
	with method B for rehabilitation and replacement	with method C for rehabilitation and replacement	with method B for rehabilitation and replacement	with method C for rehabilitation and replacement	Cabinet Office (2017b)	MLIT (2017b)	
Education	2,958.3	2,132.9	2,664.4	2,877.8	1,044.2**	862.8	2,816.8
Health	5,063.6	3,090.6	4,282.7	3,429.2	n.a.	868.8	4,172.1
Public housing	1,410.7	1,070.6	-	-	784.7 (17,801.9***)	n.a. (14,814.8***)	1,389.3
Government building	495.7	391.2	-	-	744.9	668.3	473.0

* The described figures are records from fiscal year 2016.
** Government's capital formation, including education equipment.
*** Figure in parentheses is for all type of housing including private investment.

Source: Authors

On the other hand, the estimated demand for government buildings is smaller than current investment. The reasons may be several: First, the calculations of Methods B and C both used the number of personnel who are in charge of general administrative works within governments and those employed by public corporations. This means personnel who are in charge of specific duties (Education, health, fire, police, and so on) and personnel employed under special accounting rules (the classification varies by local government, but some examples are health insurance, elderly nursing care insurance, and in some cases water/sewer and transportation) are not included in the calculation. Therefore, actual “beneficiaries” for these facilities should be much larger.

Second, the actual number of staff employed by local governments may be much larger than the estimate. The total number of current personnel for municipalities (prefectures and cities) is almost the same as the estimate. However, the statistics of currently employed personnel do not include part-time or non-tenured personnel, which consists of as much as 20% of the work force. Therefore, the actual beneficiaries may be larger than the estimate. Thirdly, recent natural disasters and redevelopment of public buildings may have affected the current investment trends, although this should still be small part of the reason.

The data on the current investment to social infrastructure shown in Table 8 is obtained from the following official statistics: 1) the statistics on government expenditure in System of National Accounts from Cabinet Office (2017b) and 2) the statistics on the commencement of construction work from Ministry of Land, Infrastructure, Transport and Tourism (MLIT) (2017b). Note that the statistics 1) covers public capital investment that forms new fixed asset and that the statistics 2) covers the cost of construction work that requires the a change in floor area. The investment amount is therefore compared with the sum of the estimated demand for new construction, rehabilitation and replacement, excluding O&M demand.

Comparison with the annual cost to sustain existing infrastructure

For further reference, another comparison of the estimated demand was made with the annual cost of sustaining existing stock volume as shown in the rightmost column of Table 8. The purpose of this comparison was: 1) To grasp the magnitude of the impacts from the difference between the estimated necessary stock volume (the basis for the demand estimate described above) and the existing stock volume; and 2) To indicate the magnitude of the expected future financial burden from a different angle from those described above. The annual cost consists of the rehabilitation and replacement cost for the existing stock volume as of 2015. The volume of infrastructure to be rehabilitated in each year of the estimate is obtained by the division of the stock volume as of 2015 by the lifetime of the infrastructure (60 years). The same formula was applied for the replacement cost.

As a result, a slight difference in the figures between the estimated demand and the calculated cost is observed, which may support the validity of the figures of the estimated demand. This difference can be explained by the difference between the estimated necessary stock volume for each year of the target period (2016-2030) and the existing stock volume as of 2015. Also, while the significance of the future financial burden to sustain the current level of social services is observed in this comparison analysis, the current level of annual investment did not meet the above-mentioned estimated demand but also the annual cost to sustain the existing stock volume as of 2015.

6. Conclusions

From the methodology used in and result of the demand estimates described above, the following points can be considered in view of extending the demand estimate methodology to other Asian countries.

1) <u>There is a substantial gap between demand and current investment</u>

The current level of investment to social infrastructure in Japan does not meet the estimated demand in the target period from 2016 to 2030 in the education, health and public housing sectors, while the country faces the challenges of aging population and financial deficit. Measures to bridge the gap, such as making public investment more efficient and mobilizing more private finance for social infrastructure development, are needed to be taken urgently. Such experience in Japan may be a key lesson for other Asian countries in formulating policies and institutions for sustainable development and operation of social infrastructure. A further study is necessary to analyze effective measures to tackle the issue of financing social infrastructure.

2) The significance of O&M, rehabilitation and replacement:

The breakdown of the estimated demand by demand type shows that the continuous infrastructure investment throughout its service life is imperative. Even in the phase of necessary infrastructure stock is decreasing due to the declining population, a considerable amount of demand for O&M, rehabilitation and replacement of existing infrastructure continues to occur throughout its service life. Such demand of infrastructure in a long term should be estimated in advance and necessary measures should be taken accordingly to respond it. Otherwise, negative impacts on the level of social services and human capital development might be expected in the long run.

3) The Key variables influencing infrastructure stock

From the exercise of estimating necessary stock volume by the micro and macro approach, it is acknowledged that volumes are mainly influenced by the change of demography and increase in income levels. For the macro approach, although our intention was to obtain the highest explanatory power for regression models, some of the explanatory variables do not have a high explanatory power such as urbanization rate and targeted population for some type of infrastructure. Therefore, it might be the role of the macro approach to complement the result of the micro approach, when extending the estimate to other Asian countries. Moreover, the price of infrastructure services, particularly the medical fee, may affect the demand of social infrastructure, while we were unable to analyze its impact in this paper due to the constraint of data availability because Japan has already introduced Universal Health Coverage over 50 years ago. It should be considered to include this factor for the next study of extending the estimate to other Asian countries, considering the framework of social security that is different country by country.

4) Adjustment for estimate methodology following each country's context:

The methodology of estimating necessary infrastructure stock volume conducted in this paper may need to be adjusted in demand estimate for other Asian countries. An infrastructure development standard used in the micro approach differs country by country and may chronologically change according to the level of income and the beneficiaries' ability to pay. The past infrastructure stock volume, the independent variable in the macro approach, may have been influenced by the conditions of the supply side in the country such as constraint of public budget or institutions when seeking to develop social infrastructure. Those features should be taken into consideration when the demand estimates are extended to other Asian countries.

5) The necessity for long term demand estimates

The difference in the estimates for rehabilitation and replacement demand between the two methods may be more evident in the context of developing countries in Asia. As mentioned above, Method C reflects the actual infrastructure stock build-up over time, while Method B reflects the estimated necessary infrastructure stock volume in the study period (2016-2030). Thus, the figures derived from Method B may be bigger than the actual demand in developing countries, where a certain volume of infrastructure has been built relatively recently and does not require rehabilitation or replacement in the study period (2016-2030). However, even when the estimated figures from Method C for the study period seems to be relatively small in such countries, it is inevitable that there will be a certain volume of rehabilitation and replacement after 2030. In addition, in a country where the necessary stock is decreasing, it may be rather optimistic to assume that rehabilitation and replacement will automatically stop, because of a downward rigidity in the removal of existing infrastructure. Therefore, an estimate over a longer duration, for instance 30 years or half the period of infrastructure service life, would help to better illustrate the real trend of infrastructure demand in the long run.

References

Akai, Nobuo, and Toru Takemoto. 2015. *Douro Infura no shourai koushinhi to jichitai betsu no zaisei futan* (Future replacement cost of road infrastructure and its financial burden by local government), Policy Research Institute, Ministry of Finance. *Financial Review* 4:113-40.

Asian Development Bank. 2017. *Meeting Asia's Infrastructure Needs*. Manilla: ADB.

Building Maintenance and Management Center. 2005. *Heisei 17 nendo ban Kenchikubutsu no Raifu saikuru kosuto* (Lifecycle cost for buildings: 2005 edition). Tokyo: BMRC.

Cabinet Office. 2017a. *Nihon no shakai shihon 2017* (Japan's Social Capital 2017). Tokyo: Cabinet Office.

———. 2017b. *National Accounts for Fiscal Year 2016 (2008SNA, benchmark year = 2011), Flow V. Supporting tables (7) General Government total outlays by function and (15) Gross Capital Formation of the Private and Public Sectors.* https://www.esri.cao.go.jp/en/sna/data/kakuhou/files/2016/2016annual_report_e.html

Cabinet Secretariat. 2015. *Heisei 27 nendo Kikou teiinn shinsa kekka.* (Results of Organization and personnel review in 2015). Tokyo: Cabinet Secretariat.

Fay, Marianne, and Tito Yepes. 2003. *Investing in Infrastructure: What is Needed from 2000 to 2010?* Washington DC: The World Bank.

Fay, Marianne, and Mary Morrison. 2007. *Infrastructure in Latin America and the Caribbean: Recent Developments and Key Challenges.* Washington DC: The World Bank.

Foster, Vivien, and Cecilia Briceno-Garmendia. 2010. *Africa's Infrastructure: A Time for Transformation.* Paris: Agence Francaise de Developpment and the World Bank.

Japan Foundation for Regional Vitalization. 2016. *Koukyou Shisetsu tou koushin hiyou shisan sofuto shiyousho (heisei 28 nendo ban)* (Specification for the software on estimation of replacement costs of public facilities and others: Japanese Fiscal Year 2016 edition). Tokyo: Japan Foundation for Regional Vitalization.

Japan Institute of Healthcare Architecture. 2017. *Shisetsu Kensaku* (Facility Search). http://jiha.sakura.ne.jp/kensaku_shisetsu.html

Ministry of Education, Culture, Sports, Science and Technology. 2013. *Gakkou Shisetsu no Roukyuka taisaku ni tsuite –gakkou shisetsu ni okeru choujumyouka no suishin* (About counter measures for deterioration of school facilities –Promotion of measures to extend lifetime of school facilities). Tokyo: MEXT.

———. 2015a. *Gakkou Kihon Toukei (heisei 27 nendo ban)* (Basic statistics on school for Japanese Fiscal Year 2015). Tokyo: MEXT.

———. 2015b. *Kouritsu gakkou shisetsu jittai toukei (heisei 27 nendo ban)* (Statistics on public school facilities for Japanese Fiscal Year 2015). Tokyo: MEXT.

———. 2015c. *Kouritsu daigaku houjin tou shisetsu jittai houkoku (heisei 27 nendo ban)* (Report on national university facilities and others for Japanese Fiscal Year 2015). Tokyo: MEXT.

Ministry of Health, Labor and Welfare. 2013. *Kaigo sa-bisu shisetsu jigyousho toukei (heisei25 nenndo ban)* (Statistics on nursing care service facility and operators for Japanese Fiscal Year 2013). Tokyo: MHLW.

———. 2014a. *Kanja toukei (heisei 26 nenndo ban)* (Statistics on patients for Japanese Fiscal Year 2014). Tokyo: MHLW.

———. 2014 b. *Iryo shisetu toukei (heisei 26 nenndo ban)* (Statistics on health care facilities for Japanese Fiscal Year 2014). Tokyo: MHLW.

Ministry of Internal Affairs and Communication. 2003, 2008, 2013. *Jutaku Tochi Toukei Chousa*. Housing and Land Survey.

———. 2005, 2010, 2015. *Kokusei chousa.* (Census). Tokyo: MIAC.

———. 2010. *Chihousai douitou kijun.* (Standards for municipal bond issuance agreements). Tokyo: MIAC.

———. 2011. *Chihou Koukyoudantai ni okeru tekiseina teiinkanri no suisin ni tuite.* (Promotion of appropriate municipal personnel quota management). Tokyo: MIAC.

———. 2015a. *Bumonbetsu shokuinsuu ichiran.* (List of the number of public officials by departments). Tokyo: MIAC.

———. 2015b. *Jumin kihon daichou.*(Basic Resident registration). Tokyo: MIAC.

———. 2016. *Toukei de miru todouhuken no sugata 2016 'shizen kankyo'.* (Regional Statistics Database (System of Social and Demographic Statistics in the 'Natural Environment'). Tokyo: MIAC.

Ministry of Land, Infrastructure, Transport and Tourism. 2016. *Heisei 28 nendo ni okeru jutakukyoku shokan jigyounikakaru hyoujun kensetuhitou ni tuite.* (Standard construction cost for projects under the Department of Housing in 2016). Tokyo: MLIT.

———. 2017a. Kenchikubutsu stock tokei. (Statistics on architectural buildings). Tokyo: MLIT.

———. 2017 b. *Kenchiku chakkou toukei (heisei 28 nendo ban)* (Statistics on commencement of construction work for Fiscal Year 2016). Tokyo: MLIT.

———. 2017c. *Shinei ippan chousha menseki santei kijun* (Area calculation standard for newly constructed general administration building). Tokyo: MLIT.

———. 2017c. *Heisei 29 nendo Kensetsu toushi mitoshi.* (Projection for construction investment in 2017). Tokyo: MLIT.

National Association Chairmen of Town and Village Assemblies. 2017. *Chouson gikai jittai chousa (giin teisuu).* (Research on actual conditions of town and village assemblies (Apportionment)). Tokyo: NACTVA.

National Association of the Chairpersons of City Councils. 2015. *Shigikai giinteisuu ni kansuru chousa kekka.* (Research result on the apportionment of city council members). Tokyo: NACCC.

National Institute of Population and Social Security Research. 2013. *Nihon no chiiki betsu shourai suikei jinkou (heisei 25 nen 3 gatsu suikei)* (Japan's future estimated population by region: estimated in March 2013). Tokyo: National Institute of Population and Social Security Research.

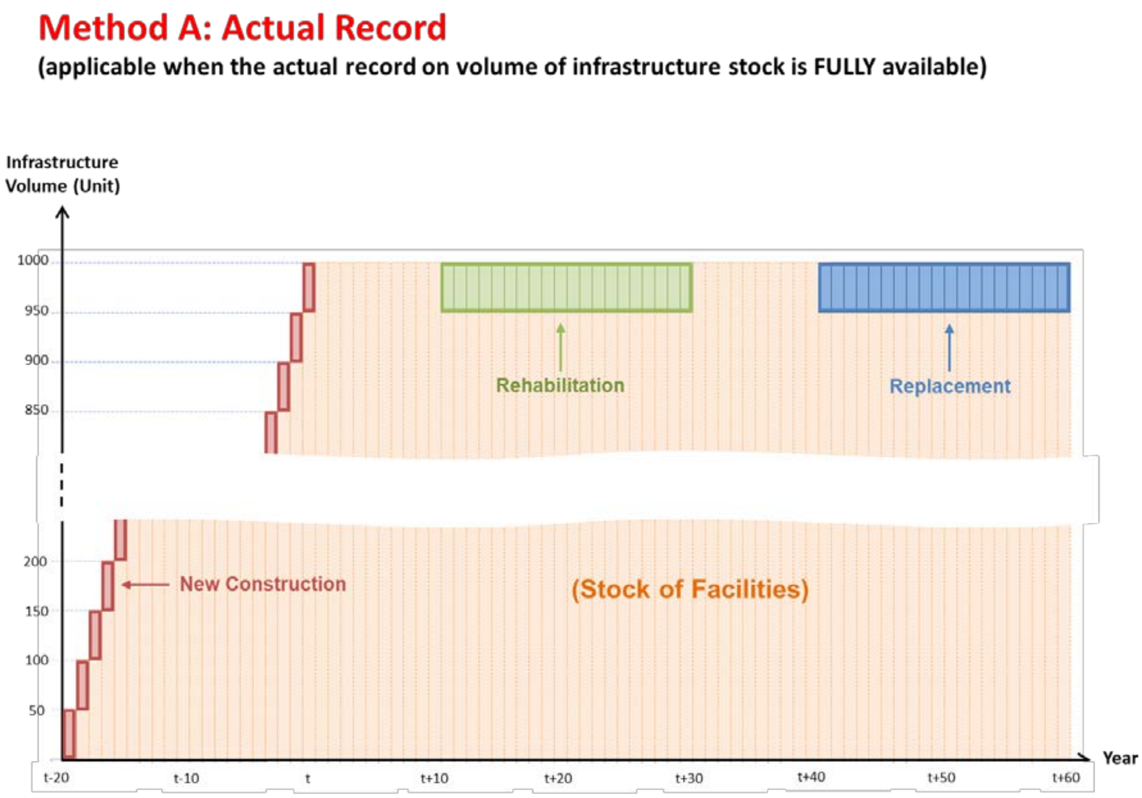
Nemoto, Yuji. 2017. *Infura roukyuka ni tomonau koushin toushi no kibo shisan (2016 nendo ban)* (Estimate for replacement investment due to infrastructure deterioration for Japanese Fiscal Year 2016). Collected papers of the Research Center for Public Private Partnership No.7. Tokyo: Toyo University, Research Center for Public Private Partnership.

OECD Data. 2017. *GDP long-term forecast*. https://data.oecd.org/gdp/gdp-long-term-forecast.htm

United Nations, Department of Economic and Social Affairs, Population Division. 2014. *World Urbanization Prospects: The 2014 Revision*. New York: CD-ROM Edition.

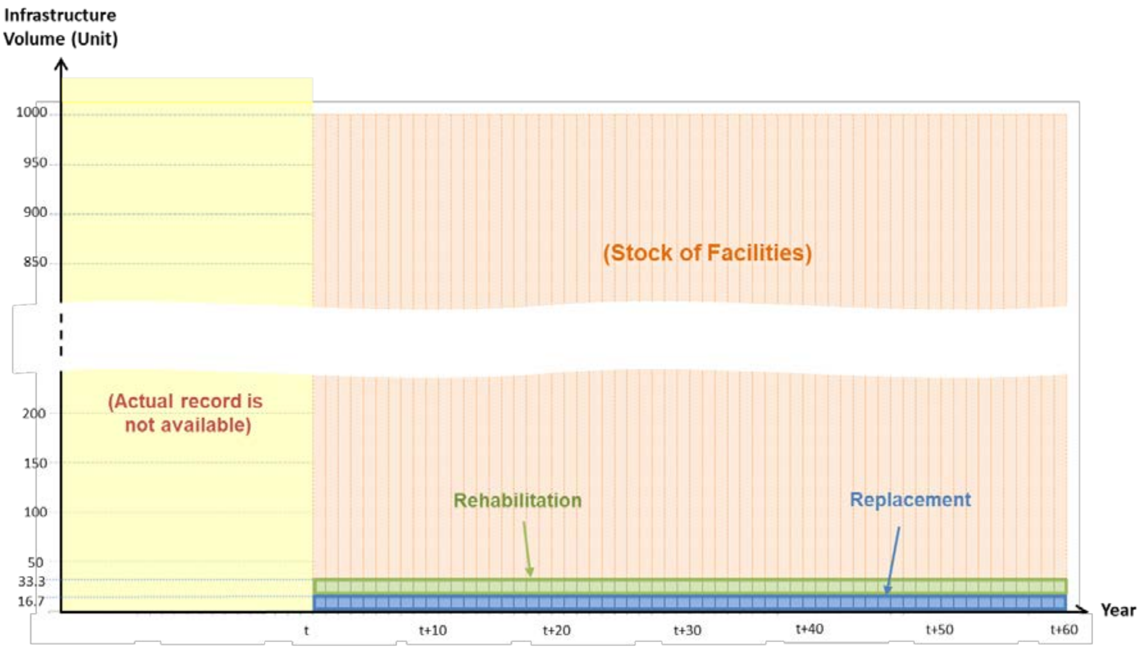
Annex 1:

Visual concept of the three methods for making rehabilitation and replacement demand estimates



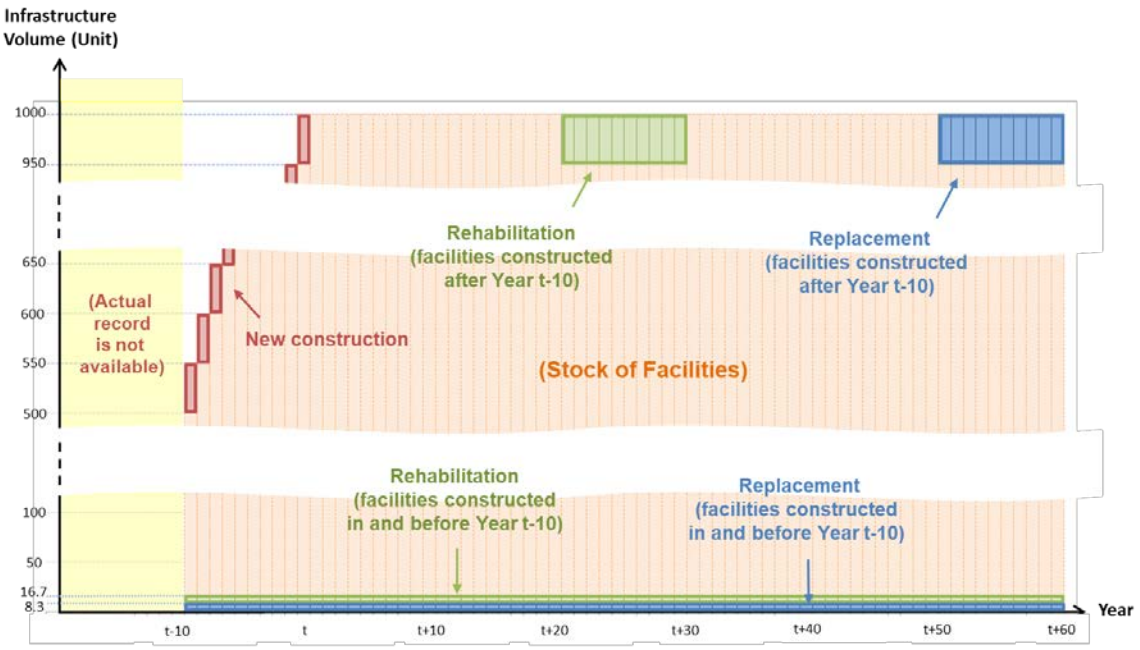
Method B: Fixed Rate

(applicable when the actual record on volume of infrastructure stock is NOT available)



Method C: Mixed

(applicable when the actual record on volume of infrastructure stock is PARTIALLY available)



Source: Authors

Annex 2:
Availability of data on actual records of past infrastructure volume and value

		Infrastructure volume				Value	
		(In floor area)		(In number of facility)		(In Japanese Yen)	
		Stock *	Flow	Stock *	Flow	Stock **	Flow
Education	Elementary school Junior high school	✓ 1952- MEXT (2013)	✓ 1952- MEXT (2013)	✓ 1960- MEXT (2015a)	✓ 1952- MEXT (2013)	✓ 1953- Cabinet Office (2017b)	✓ Cabinet Office (2017a) or MLIT (2017b)
	University Junior college	✓ 2015- MEXT (2015c)	-	✓ 1960- Ditto	-	✓ 1953- Ditto	✓ Ditto
	Kindergarten High school	✓ 2015- MEXT (2015b)	-	✓ 1960- Ditto	-	✓ 1953- Ditto	✓ Ditto
Health	Hospital Facilities for the aged	-	-	✓ 1955- MHLW (2014b) ***	-	-	✓ Ditto
	Clinic	-	-	✓ 1955- MHLW (2014b)	-	-	✓ Ditto
Public housing		-	-	✓ 1978- MIC (2013)	-	✓ 1953- Cabinet Office (2017b)	✓ Ditto
Government building		-	-	✓ 2009- MLIT (2017a)	-	✓ 1953- Ditto	✓ Ditto

* Once this data on stock is available, the flow of new construction can also be calculated by the subtraction of stock from the previous year. With the subtraction of this figure from the flow of infrastructure (all capital investments including rehabilitation and replacement), the actual record on the flow of rehabilitation and replacement may be obtained. This exercise was not conducted in this paper.

** The figures of stock in value are estimated by Cabinet office (2017b) although the raw data on the stock value does not exist.

*** In addition to the data on the number of facilities, the data on the number of beds has been available since 1975.

Source: Authors

Annex 3:
Results of regression analysis (the macro approach for infrastructure stock volume estimates)

	Kindergarten	Elementary & Junior high school	High school	University & Junior college	Hospital (Hospital Bed)	Clinic
Lagged Dependent Variable (-1)	1.452358***	1.377788***	1.065244***	1.7188***	0.9205506***	0.8712964***
	0.206	0.137	0.043	0.134	0.155	0.129
Lagged Dependent Variable (-2)	-0.5494045***	-0.4190172***		-1.113371***	-0.3086114***	-0.1171755
	0.178	0.150		0.273	0.088	0.192
Lagged Dependent Variable (-3)				0.1568996		0.7007439***
				0.271		0.187
Lagged Dependent Variable (-4)				0.1343689		-0.8461377***
				0.119		0.118
Urbanization Rate	0.1257699	-0.0528374	0.2753223***	-0.1832494	-0.3086114*	-0.5045644**
	0.106	0.070	0.077	0.124	0.179	0.215
GDP per capita	0.0144013	0.0196408	-0.081674***	0.0687548***	0.1370782***	0.0388339
	0.040	0.015	0.021	0.025	0.047	0.025
Population of target age 3-5	0.0655057					
	0.040					
Population of target age 7-14		0.0277781***				
		0.006				
Population of target age 15-17			0.0152094			
			0.013			
Population of target age 18-21				0.0183971		
				0.013		
Population (All)					1.604818***	-0.1273176
					0.312	0.127
Elderly rate					0.0144253	0.1693508***
					0.017	0.057
Constant	-0.8139091	-0.1003552	-0.7135891***	0.1691475	-23.2207***	7.879378***
	0.636	0.401	0.222	0.292	4.720	2.583
Observations	65	65	65	65	49	49
R-squared	0.9974	0.9958	0.9845	0.9974	0.9990	0.9993

Standard errors in parentheses ***p<0.01, **p<0.05, *p<0.1
The number the bttom of each variable is the standard error

Source: Authors

Abstract (In Japanese)

要約

本論文では、日本の教育・医療・公営住宅・政府庁舎の社会インフラ需要を推計した。推計は、2016～2030 年の新築・維持管理・大規模修繕・更新需要を対象とした。推計にあたっては、予測需要者数とインフラ整備基準の乗（ミクロ法)、社会経済上の変数のパネルデータを用いた回帰分析（マクロ法）の 2 つの手法を用い、各年の必要インフラストックを試算した。また、大規模修繕・更新需要について、この分野の既往文献にはない新しい試みとして、異なる 2 つの手法を用いた検討を行った。推計結果によれば、現在の社会インフラサービスの水準を保つためには、上記の 15 年間を通じて 2016 年価格で 10.3～13.5 兆円（946～1,240 億米ドル）／年の投資が必要であり、これは現在の投資水準を大きく上回る規模である。また、将来の人口減に伴って必要ストックが減少する局面でも、維持管理・大規模修繕・更新に係る支出は相当の規模となる。上記の手法と結果は、他のアジア諸国における社会インフラ需要の推計を行うにあたり、有益な示唆を提供するものである。

キーワード：病院、住宅、インフラ投資需要、維持管理、学校、社会インフラ