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SUBSTANTIAL COST BURDEN BY CROSS-SECTIONAL AND GENERATIONAL STAKEHOLDER OF A TRANSPORTATION INFRASTRUCTURE PROJECT FINANCED BY VARIOUS RESOURCES

Keiichi KITAZUME
Associate Professor
Department of Civil & Environmental Engineering
Kansai University
3-3-35, Yamate-cho, Suita, Osaka,
564-8680 Japan
Fax: +81-6-6368-0892
E-mail: kitazume@ipcku.kansai-u.ac.jp

Kazuaki MIYAMOTO
Professor
Faculty of Environmental and Information Studies
Musashi Institute of Technology
3-3-1, Ushikubo-nishi, Tuzuki-ku, Yokohama,
224-0015 Japan
Fax: +81-45-910-2593
E-mail: miyamoto@yc.musashi-tech.ac.jp

Atsushi SUZUKI

Urban Policy and Research Division
The Institute of Behavioral Sciences
2-9, Ichigayamotomura-cho, Shinjuku-ku, Tokyo,
162-0845 Japan
FAX: +81-3-5206-1680
E-mail: asuzuki@ibs.or.jp

Abstract: Various financial resources are spent on the construction and operation of an infrastructure project. Each system of financial resources differs from others, making it difficult to identify who bears the cost burden or its amount. The purpose of the current paper is to develop a model to estimate the substantial burden constitution of an infrastructure project. First, the financial resources and the social agents who substantially share them are determined and related. Second, the features of these financial resources are evaluated. Third, we develop an estimation model of the substantial burden constitution for each financial resource. Fourth, we examine the appropriateness of the model. A subway system project is analyzed as an example in which the amount of construction investment is large and financial resources, such as user fares, funds and subsidies, are varied. The study observes that some generations are forced to bear an inequitable share of the burden.

Key Words: cost analysis, generational accounting, entropy maximization

1. INTRODUCTION

The burden of infrastructure costs cannot always clearly be established. Various financial resources are spent on infrastructure construction, operation, maintenance and so on. Each financial resource system is different and the value of the substantial costs that are shared by each agent is indefinite, although the costs must be identified to develop an infrastructure smoothly. An equitable cost division may not be secured in every situation, and may delay project development.

Equity should be included with discussions of efficiency and cost sharing for an infrastructure project. However, standards and guidelines for equity have not been established, thus only efficiency tends to be discussed. Adequate equity standards and guidelines are not easily generated, but a discussion of equity among agents related to the infrastructure project should include available cost information. Detailed information concerning the division of substantial costs among agents is necessary.

Few previous articles have focused on infrastructure cost sharing. Although cost benefit analyses are frequently considered, many articles research only benefit estimating. Study interests have not been directed toward estimation of detailed costs, since the estimation of total costs is comparatively easier. However, the analysis of substantial cost sharing among agents is very difficult and should be studied. The analysis of cost sharing among agents of various financial resources is especially important. Because financial resources for infrastructure will be less than now and then more various financial resources will be procured only for recovering lack of them without detail substantial cost sharing.

Estimates of substantial cost sharing should be distributed among several generations. Many generations will benefit from an infrastructure project, which will be used over very long periods. Subsequent generations should share the project costs. However, present estimation methods do not consider the substantial costs for future generations. A model that enables estimates of cost sharing between generations is necessary before the finance scheme of project is planned. Because future generations will not be able to keep the equitable cost sharing after present generations will be died.

The purpose of the present paper is to develop a model to estimate the cost share of each agent related an infrastructure for future generations.

The present paper consists of 5 chapters. The background and purpose of this paper are expressed in chapter 1. Chapter 2 reviews existing articles regarding cost sharing in infrastructure development, and evaluates the position of these studies. We point out that few interests have been directed at cost estimating, while benefit estimating has been studied extensively. Then, generational accounting, which was proposed in the field of finance to assess the role of generations, is utilized to provide such information as a generation calculation table, discusses equity between generations.

In chapter 3, the basis concept of the cost share analysis is shown. Financial resources and social agents who substantially share the costs are identified. Methods for estimating financial resources and cost sharing agents are considered. Although cost sharing can be estimated by simple proportional allotment in many cases, a rational estimation method needs development in other cases. Using these cases, the cost share estimation model is expressed.

In chapter 4, a model that estimates the substantial cost share is developed and is applied to a hypothetical public management subway system in Japan. The appropriateness of the model is inspected through the application. The project requires a large amount of financial resources with its early period stage and is managed by various financial resources such as fare, fund, subsidy, and so forth. This model shows that certain generations of agents are forced to bear unfair costs.

Concluding remarks are presented in Chapter 5.

2. REVIEW OF COST SHARE ANALYSES

Nakagawa *et al.* (1997) estimates the overall costs of various transportation infrastructures. This research provides a macro comparison of the costs shared by each user, governments and citizens, through various financial resources for transportation infrastructures such as roads, railways, airports and seaports, but does not estimate the cost shares for individual infrastructure projects.

Auerbach *et al.* (1987, 1991 and 1994) and Kotlikoff (1992) propose generational accounting as a method of estimating fiscal policy costs over the long-term. The generational accounting indicates the total amount of receipt and payment for the whole life of each generation using fiscal policies such as pension and social security. As Auerbach *et al*. (1999) presents, generational accounting has been utilized in many countries where pension and social security problems have occurred. The life costs to future generations, in every case, tend to be much higher than for the present generation. This model warns of the possibility of future pension or social security collapse.

O'Neill (1995) points out a key concept of the generational accounting, the fundamental restriction condition that someone, living presently or in the future, must share the financial resources of a certain policy. Under this restriction, this accounting method can distribute receipt of benefits and payment of costs among all generations that are related to the policy. The generational accounting table is very useful for determining the total amount of payment and receipt throughout the life of a representative individual from each generation. The generational accounting table shows the composition of long-term receipts and payments. The information is effectively presented, enabling the discussion of cost share equity between generations.

However, few studies of substantial cost share estimation for infrastructure projects utilize the concept of generational accounting. Kitadume (Kitazume) *et al.* (1999, 2001) adopts this estimation method to determine the benefits and costs of an infrastructure project. In present study, a revised estimation framework of cost sharing among agents when various financial resources are procured is developed. Furthermore, estimation of equity is discussed, even though the estimation method is mainly a simple proportional allotment, thus a more rational method according to the features of each financial resource is required.

3. CONCEPT OF COST SHARE ANALYSIS CONSIDERING GENERATIONS

3.1 Relationship between Financial Resources and Agents

The financial resources and the agents who substantially share the costs of an infrastructure project are listed below. The financial resources are divided into 8 categories: capital/investments, subsidies, contributions, bonds, loans, funds, fares and internal reserves. Several agents share each financial resource through several other financial resources. Substantial share agents can be divided into 4 categories, nations, citizens, enterprises and users.

The method of estimating cost sharing, considering generations, is different for each financial resource feature:

(1) special use or general use;
(2) self-accounts or combining other accounts;
(3) in a limit area or wide area;
(4) repayment necessary or unnecessary; and,
(5) time lag between receipt and payment.

The financial resources for an infrastructure project are listed in Table 1, based on these features.

Table 1. Financial Resources for an Infrastructure Project

				Time Lag Between Receipt & Payment	
				No Lag	Lag
Special Use	Self-accounting			Special Use Tax	Bond
	Combining Other Accounting	Limited Area	Repayment		
			No Repayment	Capital/Contribution, Subsidy (Municipality)	
		Wide Area	Repayment		
			No Repayment	Subsidy (Government)	
General Use	Self-accounting			General Tax, Fare	General Bond, Internal reserves
	Combining Other Accounting	Limited Area	Repayment		
			No Repayment		Fund
		Wide Area	Repayment	Short-term Borrowing	Loan
			No Repayment		

The bonds and funds among these financial resources require a time lag between receipt and payment of financial resources, making it difficult to determine which agent, the amount and timing of the share, corresponded to a payment in a certain year. Subsidies were payments provided during several years. The length of the period influences the balance between income and expenditures from the project, which change the borrowed amounts or loans, and subsequently change the substantial cost shares.

There is also a potentially hidden cost share. General accounting of capital and subsidies includes several taxes with different collection standards. General accounting also considers bond financial resources requiring repayment. The different financial resources should each be considered to calculate the substantial share of costs.

In the current paper, bonds and normal taxes of general accounting are adopted as case studies to estimate the substantial share of costs. Then a hypothetical public management subway system is considered as an example. A framework of the funding estimation is showed, using a method similar to the bond estimation.

3.2 Necessity of the Cost Share Estimation Model

3.2.1 Bonds

When a project lacks the financial resources from tax revenues in a certain year, a bond may sometimes be issued. The amount of repayment due each year is settled in advance because the bond repayment plan is predetermined. The amount is the share of the cost for each year. However, if a further bond is issued before the end of the repayment period, the redemption of the subsequent bond must be included in the cost share, since the bond repayment also reduces the amount of available financial resources.

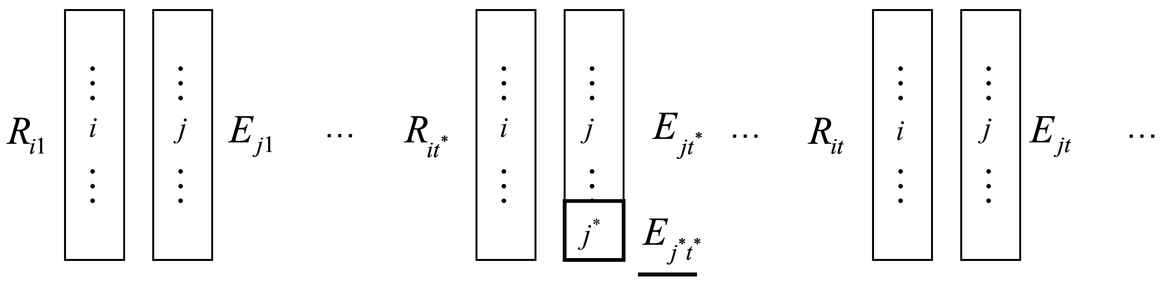
3.2.2 Normal Taxation of General Financial Resources

Taxes are collected according to established standards. For example, residential taxes are collected according to income level and property taxes are determined by the value of property. Information, including economic indicators such as population and property size, is necessary to establish a standard amount of tax payment, determine fiscal year deadlines and standardize tax revenue calculation.

Total tax revenues for each taxable asset do not correspond with each resident's tax payment aggregated on the basis of certain economic indicators. Although correspondence can be determined by totaling tax collection data individually, such work is voluminous and cannot be realistically undertaken. A model that could evaluate the correspondence between tax payment and tax revenues for each society group using set standards is needed to assist policy decision-makers.

4. DEVELOPMENT OF COST SHARE ESTIMATION MODEL

4.1 General Tax or Fare



$$
\begin{aligned}
Y_{it} &= E_{j^*t^*} \frac{R_{it^*}}{\sum_i R_{it^*}} && \left(if\ t = t^*\right) \\
Y_{it} &= 0 && \left(if\ t \neq t^*\right)
\end{aligned}
\qquad (1)
$$

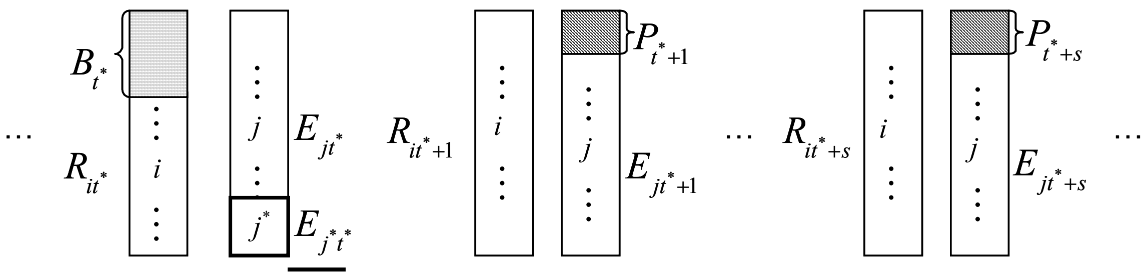
Y_{it} : Share of cost through item *i* in *t* year, R_{it} : Revenue of item *i* in *t* year
E_{jt} : Expenditure of project *j* in *t* year, * : Target year

Figure 1. Estimation Model of Cost Share in the Case of General Tax or Fare

In this case, as figure 1 shows, the share of cost corresponding to a certain project is simply calculated by distributing expenditure to the project in the year into items in proportion to share of revenue by items in the year. The cost is not distributed into other years and then all costs are burdened by the generations who are productive years old and then pay the tax to government in the year even though other generations who are children or retired people enjoy the benefit from the infrastructure, but do not pay tax to government.

4.2 Bond Issued in a Year

In the case of bond issued in a year, the figure 2 shows a calculation method. In the year, the share of cost corresponding to a certain project is calculated by distributing expenditure to the project in the year into items in proportion to share to the total amount of revenue and bond issued in the year. Then in later years, the share is calculated by distributing expenditure in proportion to the share multiplied by function of repayment to bond ratio during redemption periods. After the end of redemption period, the share will be zero. This means that some related generations will be shared the costs during redemption periods in spite of the life time of the infrastructure which may be longer than the periods.



$$Y_{it} = E_{j^*t^*} \frac{R_{it^*}}{\left(B_{t^*} + \sum_i R_{it^*}\right)} \qquad \left(if\ t = t^*\right)$$

$$Y_{it} = Y_{it^*+s} = E_{j^*t^*} \frac{B_{t^*}}{\left(B_{t^*} + \sum_i R_{it^*}\right)} f(r,s,S) \frac{R_{it^*+s}}{\sum_i R_{it^*+s}} \qquad \left(if\ t^* < t \le t^* + S\right) \qquad (2)$$

$$Y_{it} = 0 \qquad \left(if\ t < t^*\ or\ t^* + S < t\right)$$

B_t : Value of bonds in t year

P_t : Repayment in t year

f : Function of repayment to bond ratio

s : Passing year from the target year

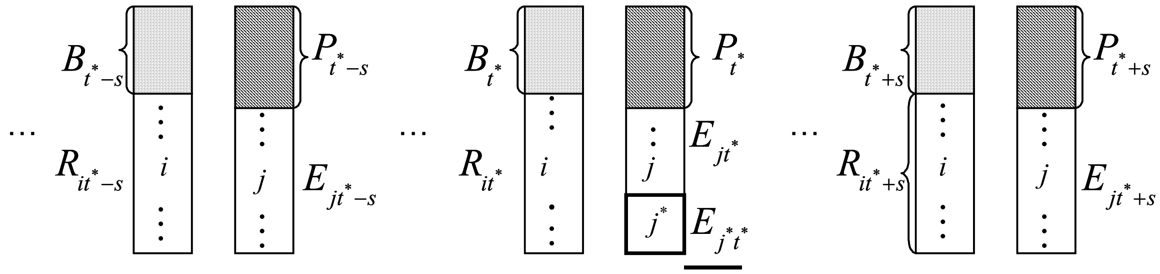
S : Redemption period

r : Interest ratio

Figure 2. Estimation Model of Cost Share in the Case that Bond is issued in a year

4.3 Bonds Issued in Several Years

Figure 3 shows the calculation method to distribute the share into years in the case that several bonds continue to be issued because of recovering lack of financial resources. In the denominator of the share, amount of repayment is included in each year. This means that the cost burden will be transferred to future generations until the cost will be perfectly burdened.



$$Y_{it} = E_{j^*t^*} \frac{R_{it^*}}{\left(B_{t^*} + \sum_i R_{it^*} - P_{t^*}\right)} \qquad \left(if\ t = t^*\right)$$

$$Y_{it} = Y_{it^*+s} = E_{j^*t^*} \frac{B_{t^*}}{\left(B_{t^*} + \sum_i R_{it^*} - P_{t^*}\right)} f(r,s,S) \frac{R_{it^*+s}}{\sum_i R_{it^*+s}} \qquad \left(if\ t^* < t \le t^* + S\right) \tag{3}$$

$$Y_{it} = 0 \qquad \left(if\ t < t^*\ or\ t^* + S < t\right)$$

Figure 3. Estimation Model of Cost Share in the Case that Bonds are Issued

4.4 Cost Share Analysis of General Financial Resources over Generations

In general, the number of taxpayers based on the amount of tax payment for each generation according to income classes can be collected as aggregated data. Suppose that we are able to know the number of taxpayers in terms of generations and income classes nationwide. Figure 4 shows, under the restriction condition, that the population distribution can be determined by generation in a certain city using the entropy maximization method.

Generation / Income (thousand Yen)	～24 25～29 65～	Total
～ 1,000 1,000～ 1,500 1,500～ 2,000 . . . 30,000～	N_{ij}	X_i
Total	Y_j	Total Taxpayer

Figure 4. Distribution of Income Class by Generation

4.5 Application to a Public Subway Project

We estimate that the construction costs of a hypothetical public subway project are three hundred billion yen. These costs are covered by private residential taxes through the general financial resources of a local government. The entropy maximization method is utilized with a restriction condition. Population of the city is assumed 1 million and typical Japanese cohort pattern is also assumed. On the other hand, benefit is assumed to be enjoyed during his or her life after the public subway is developed. Therefore, generation who is already old in the year when the subway is developed can enjoy only during remaining his/her life and then the time is shorter than younger generations. Nominal net benefit, which is benefit minus cost, is introduced for comparison analyses among generations.

The estimation results, for each generation, are shown in Figure 5. The number along the horizontal axis represents age of each generation in the first year of the project.

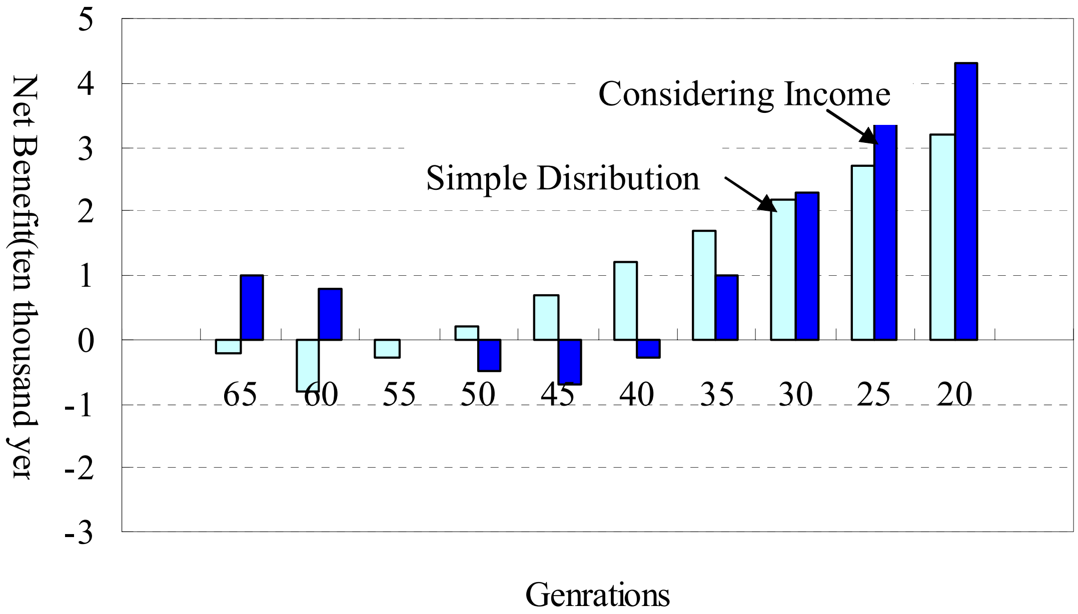


Figure 5. Generational Accounting Table by Income Class

As shown in Figure 5, the income distribution analysis estimates the cost share for the 40-55 year-old generations to be more than for a simple case, therefore their net benefits are minus, because the income of the generations is very high during the early period when the amount of investment is large.

The case that forces cost share on future generations is expected when the financial situation deteriorates because of the repayment of bond, and a subsequent bond must be issued. Share of cost by each generation for the bond issuance is shown in Figure 6. The further bond issuance increases the substantial share contributed by each generation in the future by increasing the amount of repayment of future bonds, as well as those issued currently.

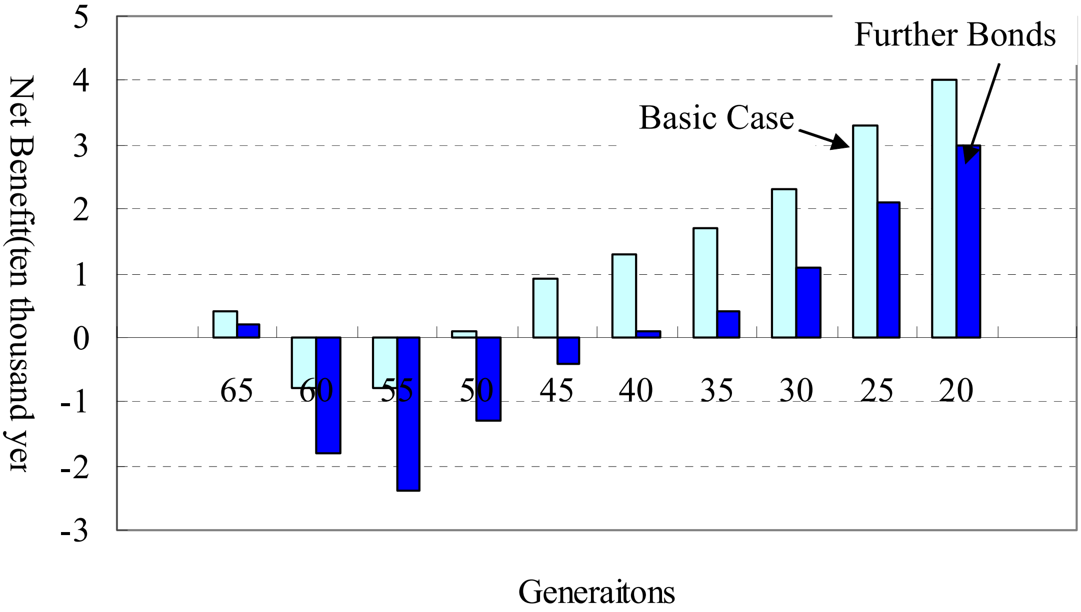


Figure 6. Generational Accounting Table in Case of Further Bonds

5. CONCLUDING REMARKS

A revised model framework that estimates the substantial share of infrastructure project costs is developed. For the model development, financial resources and agents who substantially share them are identified and related. The substantial share is estimated for each financial resource feature. We examined the appropriateness of the model by estimating the cost share of each agent. In addition, net benefit of each generation is estimated by the difference between cost and benefit. A hypothetical subway systems project managed by the public sector is taken up as an example. The amount of investment for construction in the early period stage is large, from various financial resources, such as fares, funds and subsidies. In the case that bond is focused as a financial resource, the share of costs to the 40-55 year-old generations is estimated to be higher than for other generations. Therefore, net benefit of the 40-55 year-old generations is lower than for other generations. Furthermore, the substantial share contributed by each generation in the future, as well as the present, is increased with the issuance of further bonds.

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