GENERATIONAL ACCOUNTING FOR THE DEVELOPMENT OF URBAN RAIL TRANSIT SYSTEMS

Keiichi KITADUME
Research Associate
Center for Northeast Asian Studies
Tohoku University
Aoba 06, Aoba-ku, Sendai,
980-8579 Japan
Fax: +81-22-217-7477
E-mail:kitadume@plan.civil.tohoku.ac.jp

Kazuaki MIYAMOTO
Professor
Center for Northeast Asian Studies
Tohoku University
Aoba 06, Aoba-ku, Sendai,
980-8579 Japan
Fax: +81-22-217-7477
E-mail:miyamoto@plan.civil.tohoku.ac.jp

Atsushi SUZUKI
Graduate Student
Department of Civil Engineering
Tohoku University
Aoba 06, Aoba-ku, Sendai,
980-8579 Japan
Fax: +81-22-217-7477
E-mail asuzuki@rs.civil.tohoku.ac.jp

Abstract: The transportation infrastructure requires a huge amount of cost, which is generally financed by a limited number of generations, although it is usually used not only by the generations but also for a long time over generations. Generational accounting is an ideal that deals with such structure of payment and return over generations as pension systems. The present study has developed a generational accounting system for an urban rail transit project as an example. With the system developed, it is confirmed that the cost and benefit structure is clearly illustrated in tables according to policy options, which will provide new viewpoints for project evaluation and financing.

1. INTRODUCTION

The construction and operation policies of an urban transit project tend to be strongly influenced by the quality of short term business accounts. Especially, in every Asia country including Japan, this trend is strong because urban transit projects are operated under self-supporting systems, or are financially in critical situations. Often, when policies such as a raise of fare or subsidies are decided with the aim of improving the short term business profits, the influence that the case exerts on differential cost burdens to the present and future generations is not considered. This is attributable, at least in part, to the fact that the methodologies used to calculate each generation's benefits and costs with a long term view are not sufficiently developed. Since infrastructure projects produce benefits and costs that spread along many generations, it is no wonder that planning, construction and operation should be done with attention to the long-term perspective. This is especially true of urban transit projects, given the requirement of large investments in the early stages of the project, and the large influence that construction and operation exert on urbanization. It is not, however, a desirable situation from the viewpoint of fairness, that a given generation should carry an excessively heavy burden while other generations receive most of the benefits. Therefore, there is a necessity of methods of evaluation to calculate how much share of the costs and benefits each generation will bear and enjoy.

"Generational Accounting" is now being developed as a method of project evaluation that consider such a long-term viewpoint. "Generational Accounting", mainly advocated by the science of finance, offers the tools to substantially indicate the total amount of payments and receipts due to different fiscal policies (e.g. pension and social security), during the whole life of each generation (Auerbach *et. al.*, 1987,1992,1994).

The purpose of this paper is to improve the accounts system following the long-term viewpoint advocated by "Generational Accounting" and develop a "generational accounting model for an urban transit project" suited to the analysis of urban transit projects. Furthermore, to confirm the possibility of applying the model. It is used in the analysis of a hypothetical city, since the real city is too complicate to do it.

This paper consists of 5 chapters. Chapter 1 gives the background and states the purpose of this study. Chapter 2 consists of an introduction to the characteristics of "Generational Accounting" which is advanced accounting methods with a long-term viewpoint, and a review of some topics relevant to their application to urban transit project. The basic model of generational accounting for an urban transit project is developed on the basis of these topics in Chapter 3. The framework to clearly calculate the benefits and costs from an urban transit project for each generation along its service life is shown, even though many premises had to be included here. The basic model is then applied to a hypothetical city in Chapter 4, and it is confirmed that it is able to express the difference in the receipt and payment between generations. Furthermore, we explore how the outcome changes, especially after considering the externality of the premises in the basic model. The results obtained from the application of the model to a hypothetical city and the significance are summarized in Chapter 5.

2. APPLICABILITY TO URBAN RAIL TRANSIT PROJECT

2.1 Accounting System from the Long-term View Point in Other Fields

“Generational Accounting” is an accountability system that is able to express the balance of the costs and benefits in a generational accounting table, by showing the total amount of the benefits that are received and the costs that are paid during the whole life of every generation. The system is proposed in the field of science of finance to clarify the problem that social security programs will represent in the future, at a time when the so-called baby boom generation would grow older and consequently financial burden would become the responsibility of future generations. Financial deficit accounted in simple fiscal year does not fully capture the real situation of the social security system, since social security amounts that currently increase the stock but will be paid in the future by the government, are expressed as black figures. “Generational accounting”, on the other hand, can express such a long-term income and outgo balance. In addition, as this accounting system effectively puts forward all the relevant information, is able to show the structure of long-term costs and benefits, thus laying the table for discussing the fairness of the burden between generations (Kotolikoff, 1992).

“Generational accounting” is calculated in the following manner. The government that implements fiscal policies and the population that enjoy the benefits and share the costs are considered as the agents. Furthermore, population is divided in terms of generations. First of all, government expenditure is constrained by the budget constraint equations

(1),(2). Each term of this equation is rebated to present value. These equations mean that the debt of the government as net value does not expand.

$$\sum_{s=0}^{D} Y_{t,t-s} + \sum_{s=1}^{\infty} Y_{t,t+s} + W_t^{g} = \sum_{s+t}^{\infty} G_s \prod_{j=t+1}^{s} \frac{1}{(1+r_j)} \qquad (1)$$

$$Y_{t,k} = \sum_{s=\max(t,k)}^{k+D} T_{s,k} P_{s,k} \prod_{j=t+1}^{s} \frac{1}{(1+r_j)} \qquad (2)$$

$Y_{t,k}$: the time t present value of remaining lifetime net payments of the generation born in year k
W_t^{g} : the government's net wealth in year t, plus the present value of government consumption
G_s : the government consumption expenditure in year s
$T_{s,k}$: the projected average net payment to the government made in year s by the generation born in year k
$P_{s,k}$: the number of surviving members of the cohort in year s who were born in year k
D : the maximum age of life
r_j : the pretax rate of return in year j

The first term on the l.h.s. of (1) adds together the present value of the net payments of all generations alive at time t. The term on the r.h.s. of (1) stands for the net value of all government consumption expenditure. It is possible to calculate these while using the prediction value of real interest rate and of future population of cohort, under the premise that the present share structure of benefits and costs will remain unchanged. Accordingly, the second term on the l.h.s. which represents the present value of the net payments of future generations can be calculated. This is distributed to each generation by appropriate distribution parameters. So we are able to know $Y_{t,k}$ which means the time t present value of remaining lifetime net payments of the generation born in year k. Adding together the receipts and payments for the life of every generation, these are summarized in tabular form in the so-called "generational accounting table".

From "Generational accounting" the following suggestions are taken to be applied to a long-term urban rail transit project.

(a) The balance of the receipt and payment in the simple fiscal year, does not necessarily agree with that of the receipt and payment of the whole life. Therefore, the effect of the policy should not be evaluated in a cross section but by the balance of the receipt and payment of the whole life with regard to generations.
(b) Although standard parameters to evaluate intergenerational fairness are not offered, effective use of the previously presented, especially the "Generational accounting Table", enables us to objectively discuss fairness issues.
(c) As it can be seen from the budget constraint equation, population of cohorts largely influences the value of the receipt and payment of each generation.

2.2 Applicability to Urban rail transit Project

There are some problems to the application of "Generational Accounting" concepts, as it is, to an urban rail transit project. The following points need to be considered based on the specific characteristics of transit infrastructure projects.

(a) The amount of subsidy to the construction costs during a limited period and the fare amount that will be changed during the operations period, will become a large factor of difference among generations. Such factors must be considered as indications because of their coexistence.
(b) There are considerable external benefits and costs to the areas surrounding an urban rail transit project. The scheme needs to go beyond the analysis of mere profit projects, and be structured to consider the effects to areas in the periphery of the project.
(c) The burden of fiscal policy and the value of resources or environmental assets do not present large variations among individuals in the same generation. However, receipts and payments inherent to an urban rail transit project rely on individual choices, as for example, residence selection, transportation mode choice and so on. It is then necessary to originally calculate the receipt and payment of each person choosing different alternatives, using a number of choice behavioral models.
(d) There are many agents relating to an urban rail transit project, for example, local government, passengers, periphery dwellers and competing transportation companies. Therefore, relations with their receipts and payments become complicated.
(e) The assumption that the structure of the payment and receipt will not change in the future is set up, when the total amount of receipt and payment is distributed to each generation. However, when efficiency and productivity of the system are improved, or transit-use promotion campaigns are done, it is expected that changes to the receipt and payment structure in terms of generation will occur. The present scheme is unable to treat this kind of changes.

The present paper focuses on factor (a) , develops a basic model and establishes several premises about factors (b)～(e). However, that effective information is able to be offered to the structure of the receipt and payment between generations holds even under such rough premises.

3. BASIC GENERATIONAL ACCOUNTING MODEL FOR AN URBAN RAIL TRANSIT PROJECT

3.1 Basic Concept

The purpose of this model is to summarize the real value of urban rail project related receipts and payments through the whole life of each generation of inhabitants. The basic years of the realization are their birth years respectively as to the future generations. It is for this reason that the future generations will not be able to receive the benefit and pay the cost estimated at the present value since they are not alive now. If the receipts and payment of the future generation are realized at the present value, we turn out to underestimate them.

Here, we calculate the difference between receipts and payments among generations and the burden of the subsidy and the fares before and after the end of the redemption period, subject to the constraint that profits of the project will be kept in the long run.

3.2 Premises

A hypothetical city is set up for the basic model. The city consists of two areas. One is a residential area where all citizens inhabit and the other is the area where firms and schools locate, so that all the working and school commuting concentrates here. A urban rail transit ties two areas in one station and a road also ties them. In addition, it is assumed that there is no resident migration, neither into the zone or out of it. The agents considered within this framework are the urban rail transit, the local government and city residents.

3.2.1 Urban rail transit

The urban rail transit offers the city traffic service that represents a time saving effect to the users, and receives from them an established fare in compensation. It competes with car for the city traffic service. Therefore, if the fare increases, the number of passengers will decrease. The income of the urban rail transit company dose not always increase when it raises the fare.

Also, it receives from the local government a subsidy amounting to a fraction of the construction investment, as will be shown later.

3.2.2 Local Government

The local government raises taxes from citizens according to their income level, which then become financial funds useful to subsidize the urban rail transit company. The subsidy covers a fraction of the construction investment and is paid at established periods. At this point, the premises are the proportion of costs that the subsidy will cover and the period. The fund resources in each year are the general financial resources for the same period. Residents who are productive share the general financial resources, which can also be seen as the opportunity cost paid by means of the financial resources not utilized in other projects.

3.2.3 Residents and Urban Rail Transit Users

The residents and the urban rail transit users are considered as the same in this model. All citizens choose the rail transit or car as a transit mode. If they choose the rail transit, they receive the city traffic service from the urban rail transit company and pay the corresponding fare. Furthermore, residents pay to the local government a tax that corresponds to their income level whether they choose the rail transit or car. However, only the residents that are of economically active age receive income, pay the tax to the local government and share the subsidy indirectly. It is assumed that every economically active person has the same amount of income. The economic status of residents with respect to their age, is set up in Table 1. Besides, it is supposed that there are not residents over 80 years old. Although different from a real system, these setting do not represent a lose of generality, when the receipt and payment in terms of generations are considered

Table 1. Setting of the Cost Burden in Terms of Age

Age	Cost Burden
0 ～20	Use urban transit, however do not pay the tax
20～60	Use urban transit, and pay the tax
60～80	Use urban transit, however do not pay the tax

3.3 The Basic Model

3.3.1 Balance of the Urban Transit Operation

Equation (3), consistent with current business accounting practices, states that the property of the urban rail transit company in a simple fiscal year is comprised of capital and debt.

$$A_t = M + S_t + L_t - D_{t-1} + N_t + D_t \tag{3}$$

A_t : the value of property in year t
M : the common stock
S_t : the subsidy total amount in year t
L_t : the long-term debt balance in year t
N_t : the net profit or loss in year t
D_t : the deficit in year t

A_t is depreciated every year. The amount of long-term debt is a fraction of the total amount of initial investment for which funds were lacking. These values can be calculated for each year, since the construction cost and the common stock are given exogenously. N_t is obtained for year t from equation (4).

$$N_t = p_t X_t - (C_t + r_l L_t + r_s D_{t-1}) \tag{4}$$

p_t : the fare of the urban rail transit in year t
X_t : the number of passenger in year t
C_t : the operation cost in year t
r_l : the interest rate to a long-term debt
r_s : the interest rate to a short-term borrowing

Several detailed items with regard to X_t and C_t are given exogenously. The values of r_l and r_s are also given exogenously. The financial situation in year t-1 that is passed over to year t and N_t can be calculated sequentially, after equations for the previous year have been solved. It is clear that if the amount of fare income or the subsidy are small, short-term borrowing and its interest burden will increase and affect the good financial situation in the long run.

3.3.2 Balance of the Local Government

Equation (5) represents the local government's receipts and (6) the payments, under the conditions described in 3.2.2.

$$I_{gt} = \tau_{gt} n_{i \cdot t} \tag{5}$$

I_{gt} : the receipt of the local government g in year t
τ_{gt} : Tax rate that is collected from the residents in production age
$n_{i\cdot t}$: the production age population in year t

$$O_{gt} = S_t - S_{t-1} \tag{6}$$

O_{gt} : the payment of the local government in year t

3.3.3 Balance of the Urban Rail Transit Users

Equation (7) represents the receipt of residents, also urban rail transit users, and (8) the total amount of their payments.

$$I_{ct} = U X_t \tag{7}$$

I_{ct} : the receipt of the residents C in year t
U : the benefit per passenger from the urban rail transit

$$O_{ct} = p_t X_t + \tau_{gt} n_{i\cdot t} \tag{8}$$

O_{ct} : the payment of the residents C in year t

3.3.4 Constraint

A budget restriction, stated as equation (9), is introduced for the urban rail transit company to keep the balance of income and outgo in the long run.

$$\sum_t^{ID} N_t / (1 + r^t) = 0 \tag{9}$$

ID : the project period of the urban rail transit
r : the discount ratio

The fare is calculated from equation (9), since the number of passenger does not change with fare changes if no other competing modes operate in the area.

3.3.5 Generational Accounting

In the generational accounting table are summarized the receipts and payment in terms of generation of residents. On this table, the receipts and payments for the whole life of the project are calculated for all generations, starting with those who were 80 years old on the year when the urban rail transit project started, up to the generation born on the year when the service period of the project expires.

If every citizen uses the urban rail transit the same number of times every year through all its operational life, the receipt of residents obtained from the equation (7) does not change by generation nor age. However, the payment given by equation (8) depends on the age of a generation at a given project stage. The subsidy is exercised at an early stage of the project and just for a limited period. The generations that are of productive age during this period share the subsidy burden indirectly. Also, the generations that are users of the urban rail transit before the redemption, share the burden of repayment of the short-term borrowings and their interest indirectly by paying the fare. The generations that use the urban rail transit after the redemption receive the benefits of a reduced fare or some merits given by the surplus funds. The receipt and the payment per person of generation i are given by equations (10), (11) and individually by equations (7), (8) .

$$\sum_{t=1}^{i+D} B_{it} = \sum_{t=1}^{i+D} UX_t / (\sum_i n_{it}) \tag{10}$$

$$\sum_{t=1}^{i+D} C_{it} = \sum_{t=1}^{i+D} p_t X_t / (\sum_i n_{it}) + \tau_{gt} \tag{11}$$

where

$p_t = p$ (if $t \leqq t^*$)
$p_t = p^* < p$ (if $t > t^*$)
$\tau_{gt} = 0$ (if $t > T$)

B_{it} : the receipt made in year t by the generation born in year i
C_{it} : the payment made in year t by the generation born in year i
n_{it} : the number of surviving members of the cohort in year t who were born in year i
D : the maximum age of life
t* : the year when the borrowing and debt will be zero
T : the period of subsidy

4. APPLICATIONS TO A HYPOTHETICAL CITY

4.1 The Cohort

The basic model is applied to a hypothetical city. The cohort is a factor that brings about a large effect to the receipts and payments structure in a generational accounting table. Tables are calculated on trial for two cases. In case 1, the population of every cohort is always equal to that of others from the beginning of the project. The population of every cohort turns out to be 250 thousands. In case 2, the population of the new cohort which will be born in the future is 200 thousands. Therefor, the total population will be decreased in the future. The concrete settings selected for every case are shown in Table 2. The authors selected these values optionally, but basing their estimates on the balance of items of an actual urban rail transit project.

Table 2. A Hypothetical City and an Urban Rail Transit Project for the Case Study

Common stock	30 billion yen	Depreciation	Straight-line method, 60 years(10% salvage)
Subsidy(amount)	168 billion yen		
Subsidy(period)	10 years equally	Population	(Case1,3) 1 million (Case 2) Decreasing 50 thousands by 20 years
Long-term debt	60 billion yen		
Interest rates	4 %		
Charges	1.1% of construction cost	Time saving value	25 yen / minute

The calculation results are shown in Table 3. Repayment of borrowings and debts is due to be over in 40 years for each case. The fare is estimated at 232 yen in case 1 and at 242 yen in case 2. Even if the fare is reduced to 166 yen in case 1 and to 183 yen in case 2 after the repayment, operating costs at subsequent stages can be covered exclusively by the fare collection. In every case, we observe that present generations are bearing a heavier burden in comparison with future generations. There are two reasons. One is that life of the present generation is shorter to enjoy the benefits brought by the urban rail transit system than the future generation. Another is that only the generation 2 and 3 share the burden of the subsidy, since they are the residents that are of economically active age during the period of subsidy.

Table 3. Generational Accounting Table for Case 1 and Case 2

(thousand yen)

Generation	Age*1	Case 1			Case 2		
		Receipt	Payment	Net Rec.*2	Receipt	Payment	Net Rec.
1	60	1,351	1,254	97	1,351	1,308	43
2	40	1,968	2,053	- 85	1,968	2,132	- 164
3	20	2,249	2,240	9	2,249	2,338	- 89
4	0	2,378	2,098	279	2,378	2,205	173
5	-20*3	2,378	1,935	442	2,378	2,059	318
6	-40	2,378	1,579	799	2,378	1,740	637
7	-60	2,378	1,579	799	2,378	1,740	637

*1 Age at the time when the project begins.
*2 Net Receipt = Receipt − Payment
*3 - 20 means that the generation will be born 20 years later.

Additionally, in case 2, the difference of net receipts among generations decreases in comparison with case 1. The differences between the maximum net receipt and minimum one are 884 thousand yen in case 1 and 801 thousand yen in case 2 respectively. It is for this reason that all generations share the burden of the total operational cost of the rail transit systems by paying the higher fare than case 1, since the population of the future generation which will burden the cost in the future is less than case 1. In both cases, "Generational Accounting" lets us express the difference in terms of a generation, even under fundamental premises.

4.2 External Benefits and Costs

An urban rail transit brings about external benefits and costs to the area in the periphery of the service. It is proposed that the project financial situation should be improved by returning part of the external benefits through the local government, so that external benefits becomes endogenous in the project finance, thus approximating it to the optimal arrangement of social resources.

The amount of external benefits basically depends, among other factors, on the size of the urban rail transit project, the number of passengers, and the land conditions in the periphery area. However, we suppose that the same amount of external benefit as the investment scale impinges on land prices all over the residential area equally, and that half of the benefits are converted to rent with the long term rate of interest and returned to the urban rail transit project as case 3. Equations (4)~(8) are respectively modified as follows.

$$N_t = p_t X_t + 1/2\tau_v A_0 - (C_t + r_l L_t + r_s D_{t-1}) \quad (4')$$
$$I_{gt} = \tau_{gt} n_{i\cdot t} + 1/2\tau_v A_0 \quad (5')$$
$$O_{gt} = S_t + 1/2\tau_v A_0 \quad (6')$$
$$I_{ct} = U X_t + \tau_v A_0 \quad (7')$$
$$O_{ct} = p_t X_t + \tau_{gt} n_{i\cdot t} + 1/2\tau_v A_0 \quad (8')$$

Table 4. Generational Accounting Table for Case 3

(thousand yen)

Generation	Age*1	Case 3		
		Receipt	Payment	Net Receipt
1	60	1,355	649	707
2	40	1,974	1,172	802
3	20	2,256	1,271	985
4	0	2,385	1,089	1,296
5	-20*2	2,385	1,010	1,375
6	-40	2,385	837	1,548
7	-60	2,385	837	1,548

*1 Age at the time when the project begins.
*2 - 20 means that the generation will be born in 20 years later.

The results of estimation are shown in Table 4. The fare is estimated at 120 yen and it is able to provide for the operational cost at a reduced fare of 88 yen after repayment of borrowings and debts is over. The receipt of every generation increases because of the return of external benefit. Moreover, the difference between generations is decreased, since the inexpensive fare bring about large net receipt with respect to all the generations and covers the unfairness that the present generation shares the heavy burden of the subsidy.

5. CONCLUDING REMARKS

The present study confirms the appropriateness of a generational accounting model for an urban rail transit project by applying "Generational Accounting" principles, that are long-term project evaluation models studied in other fields, to an urban rail transit project in a hypothetical city. Although subject to a number of simplifying assumptions, the following was learned:

(a) A system of short term subsidies for the construction of transit facilities becomes a factor of excessive burden to certain generations that contemporaneously share fund resources. The impact to unfairness is severe, since the construction cost of an urban rail transit facility usually involves the expenditure of considerable sums of money.
(b) For generations sharing the subsidy of large sums of money during the early stages of the project, life is short to enjoy the benefits brought by the urban rail transit project. Therefore, such generations do not get enough benefits during their lifetime, in spite that are paying a heavier share of the costs than future generations.
(c) Fare changes dictated by the logic of short-term reasons, such as a bad financial year, becomes the cause of long-term unfairness among generations. The fairness of the burden shared by many generations needs to be considered, in spite of a number of complicating factors.

We were able to represent the items described above quantitatively by estimating the receipts and payments under a generational accounting framework.

Still, there exists a possibility that unfairness might occur in others ambits such as pension policy and tax burden, even if unfairness in an urban rail transit project is subdued. Therefore, simply using a generational accounting table for an urban rail transit project should not be taken to be a comprehensive plan to eradicate unfairness. Nonetheless, it is important to apply such useful information tools that consider fairness between generations to the analysis of several policies.

The significance of the generational accounting system is to offer good information beforehand, in case that there are irreversible factors that we are unable to modify, like the burden of a project. Urbanization, development of traffic facilities, urban environmental problems and other effects are irreversible or are prohibitively costly to modify. Accordingly, it is becoming especially important to consider these subjects during the evaluation stage, using a long term evaluation model like the one presented here.

ACKNOWLEDGEMENTS

This study is supported in part by a grant from the East Japan Railway Culture Foundation. The authors acknowledge the organization with deep gratitude.

REFERENCES

Auerbach, A.J. and Kotlikoff, L.J. (1987) **Dynamic fiscal policy**, Cambridge University Press, New York.

Auerbach, A.J., Gokhale, J. and Kotlikoff L.J.(1992) Generational Accounting: A New Approach to Understanding the Effects of Fiscal Policy on Saving, *Scandinavian Journal of Economics*, **94(2)**, 303-318.

Auerbach, A.J., Gokhale, J. and Kotlikoff L.J.(1994) Generational Accounting: A Meaningful Way to Evaluate Fiscal Policy, *Journal of Economic Perspectives*, **Volume8, Number 1**, 73-94.

Kotlikoff, L.J.(1992) **Generational Accounting - Knowing Who Pays, and When, for What We Spend.**, The Free Press, New York.

Kitadume, K. and Miyamoto, K.(1997) An Approach to Urban Transportation Project Evaluation from the View Point of Generational Accounting, *Proceedings of Infrastructure Planning,* **No.20(2),** 387-390.