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Theoretical Criteria for the Expressway Toll-Pooling System in Japan

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Abstract

The purpose of this paper is to analyse merits and demerits of the expressway Toll-Pooling System (TPS) and to examine the basis for introduction of TPS in Japan.

It is proved that from the social-welfare-maximization point of view TPS is *not inferior* to the Self-Supporting Accounting System By Root (SSASBR) other things being equal. The economic basis, income redistribution effects, and institutional constraints of TPS are analysed on quasi-dynamic investment criteria.

We conclude that the institutional constraints can only be a check for the introduction of TPS.

Key Words: Expressway toll-pooling system, Self-supporting accounting system, Quasi-dynamic investment criteria.

1. Principle of the Self-Supporting Accounting System

The properties of such a goods•service that will become barely consummable by the appropriation of big-push public projects (we call it to be *social overhead capital service*) are that (α) 'market' of the goods•service concerned is not formed *automatically* in the (competitive) market mechanism (without some interventions transcending individual economic unit); and, though being rarely a case, (α') 'market' can be automatically formed and continues in the market mechanism only in the non-competitive market mechanism; and (β) the most part of indirect economic effects which are to constitute the 'social benefits' being generated by the accommodation of the goods•service concerned reside in this 'non-marketability', *in the meaning* that it results in the total values which will be obtained by summing up what is formed, in incidence basis, owing to the *technological* (*non-marketable*) external effect in the stage of generation having been propagated and dispersed marketably or non-marketably; though this is partly a dual property of (α) and

(α')[2].

Here exists the meaningfulness of the public investment criteria (of course, including public-fare policy) that intend to allocate optimally scarce resources by the interventions transcending individual economic unit.

Though Hotelling Proposition (the principle of marginal cost pricing)[4] is the logical conclusion beyond further dispute provided that we should expect the function of efficient resource allocation to the price mechanism, it leaves unsolved such a problem as 'Reasonable Cost Burden (RCB) (reasonable interpersonal allocation of cost burden)' whether we should subsidize the deficit resulted in the public utility or the special account which takes charge of production of the social overhead capital services by the general account or not, depending upon the value judgement in the optimum income distribution[3].

What should we mean by a 'Principle of the *Self-Supporting Accountability*' or 'the *Self-Supporting Accounting System* (SSAS)' in the public fare policy being intended shor-trun demand-supply adjustments on the premise that there is a public investment criteria, or certain amount of social overhead capital facilities which generates social overhead capital services. It (SSAS) is intended to solve the problem of 'Reasonable Cost Burden' by charging all the average cost of the social overhead capital service concerned (most of which will be capital costs) to the direct users in some form of fares, based upon the '*Principle of Beneficiary Burden* (PBB)' even if we might infringe Hotelling Proposition, that is, sacrifice the efficiency of resource allocation.

To be conrete, it (SSAS) is what prescribes one constraint condition which fulfils its function in the optimal problem of public fare policy or public investment criteria, in the meaning that the time series of public fare rate must be optimized under the constraint (we call it to be Self-Supporting Accounting System Constraint) that the total revenues taken into account over the planning horizon (e. g., amortization term) of the public project concerned must be equal to or more than the total costs, in a case where certain amount of social overhead capital facilities is presupposed ; or the time series of public fare rate of the social overhead capital service being supplied by the set of the public project for which public funds are scheduled to be allocated must be optimized under the constraint of satisfying the above-mentioned financial viability ($\equiv$ the total revenues taken into account over the planning horizon minus the total costs equals non-negative), which should be simultaneously determined with the optimization of allocation of the public investment.

2. Self-Supporting Accounting System By Route *vs.* Toll-Pooling System

Under the current toll-ordinal highway system in Japan, the constraint of the self-supporting accounting system is set by each route [we call it to be *self-supporting accounting system by route* (SSASBR)]. It is understood that, for this, each route is considered to be one *social overhead capital facilities en bloc*, for which the public fare policy or public investment criteria subject to the constraint of the

self-supporting accounting system can be applied.

The national intercity expressways system (NIES) is structured with the intention that each route (each Traversing Expressway or each Crossing Expressway) as a constituent of it should be gathered and 'connected organically to constitute the national principal transport network'[1] and create multiplicative and accumulative effects beyond the simple additive sum of benefits of each route measured by itself. However, supposing that the self-supporting accounting system were applied for the NIES, in the same way as for the current toll ordinal highways system, and if even a route incapable of satisfying the self-supporting accounting system in this NIES is included, then it will be excluded from the choice bundle (set) of public investment criteria, being incompatible with the SSASBR, no matter what large contribution the NIES may create to the national economic welfare (in case of the public investment allocation). Namely, to apply the SSASBR to the NIES means that *there exist some possibilities which lose the opportunity realizing the national economic welfare* which is a concept in the more high ranking (than benefits) all the while.

A toll-pooling system (TPS) is the one in which we *regard the NIES as one social overhead capital facilities,* and apply for it the theory of public fare policy or public investment criteria subject to the constraint of the SSAS.

Under this TPS, even if a NIES includes some routes which do not satisfy the SSASBR (in case of public investment allocation), it has a tendency to work towards the diminishing of the possibilities above-mentioned to a great extent, in the meaning that this NIES is not excluded from the option bundle of public investment criteria, if only it satisfies the principle of the SSAS in such procedures as subsidization by the whole NIES, namely transfer of subsidies from the surplus route to deficit route, or pooling toll revenues obtained from the NIES on the whole, and then charging costs due to it with this pooled funds.

If it is supposed that (a) we take up only an efficient allocation problem of resource for consideration, and (b) there does not exist inefficiency on resource allocation or difference in costs which may well occur in managing both systems, then we can infer clearly that the TPS is a *weaker* constraint than the SSASBR, from the fact that either of both systems is to function as a constraint in the optimization problem which is intended to maximize the National Economic Welfare (NEW), that is, public fare policy or public investment criteria, and any NIES satisfying the SSASBR satisfies, without fail, the TPS ; so that it can be qualitatively concluded that *there does not exist the proposition that the TPS were less inferior to the SSASBR,* in the meaning that it is absolutely impossible that the optimum value of the National Economic Welfare attained by the TPS were less than that by the SSASBR.

As the actual national economy has such a production structure that each industry with the subscript of region is connected organically each other, and works with the interdependent structure being dependent vertically and horizontally, the possibility will be enhanced that it will be concluded that the TPS will be as much

superior to the SSASBR in case of (a) and (b) above-mentioned being presupposed, as there is a high possibility that the NIES stimulates to make these organic activities more efficient, or to change them to a new organic interdependent relations by which *more high level of the NEW* can be obtained. It is not too much to say that the TPS, in the meaning above-mentioned, is intended to utilize optimally the productivity of the NIES which will contribute to the national economy in the form of transport network, by retreating the principle of the SSAS to some extent.

However, since this TPS will make the principle of the SSAS, above all, which includes the PBB, retreat to some extent, naturally there arises such a problem as does not occur under the 'SSASBR' and particularly a problem concerned with the 'RCB'. Consequently, in such a case where these problems may be contradictory to the realization of precondition (a) and (b) above-mentioned, it need scarcely be said that the qualitative superiority of the TPS will no longer hold over the SSASBR. Fundamentally, it is necessary that these problems will be dealt with case by case. (As will be described later on, even in a case where a so-called income redistribution problem is dealt with, namely the precondition of (a) does not hold there is a high possibility that the superiority of the TPS will actually hold over the SSASBR)

3. Quasi-Dynamic Public Investment Criteria

According to the ideal dynamic investment criteria, the time trajectory of the optimum NIES under the TPS should be derived by analyzing the time trajectories of the transport route construction which will maximize the present aggregate value over the infinite period and fare rate system of these construction routes, subject to the constraint that the total revenues are equal to or larger than total costs, and funds in each use satisfies their opportunity cost criteria, based upon the data such as the pooled set of transport routes feasible for selection, time series of available funds, various forms of technical function, and their time series, etc.; however, here, being in closer touch with reality, we intend to try in the first approximation to derive the time trajectory of the optimum NIES, by examining all the conditions for selection of a new transport route (usually, this is a deficit route by itself) under the TPS.

Now let us consider to construct and add a new route (we call it to be π route) to the NIES composed of the specified n routes for each τ time (which we show to be H_n). We show the NIES newly set up to be H^{π}_{n+1}. The SSAS constraint set by the TPS is shown as follows:

$$G_n(\tau)+C^{\pi}+\sum_{t=\tau}^{T^n_{n+1}}\frac{1}{(1+\rho)^{t-\tau}}M^{\pi}_{n+1}\left(t,{}^{\pi}P^{n+1}_1(t),{}^{\pi}P^{n+1}_2(t),\cdots,{}^{\pi}P^{n+1}_{n+1}(t)\right)$$
$$\leqq\sum_{t=\tau}^{T^n_{n+1}}\frac{1}{(1+\rho)^{t-\tau}}R^{\pi}_{n+1}\left(t,{}^{\pi}P^{n+1}_1(t),{}^{\pi}P^{n+1}_2(t),\cdots,{}^{\pi}P^{n+1}_{n+1}(t)\right),\qquad(1)$$

where,

$G_n(\tau)$=the amount of the loan unredeemed of H_n for τ time which is deter-

mined depending upon the time series of construction trajectory of H_n and fare rate system (up to τ time);

C^{π}=construction costs of π route;

${}^{\pi}P_i^{n+1}(t)$=time series of fare rate system of i route in the set of H_{n+1}^{π} (on and after τ time) $(t=\tau, \tau+1, \cdots)$;

$M_{n+1}^{\pi}(t, \cdot)$=time series of management and operation expenses of H_{n+1}^{π} (on and after τ time) $(t=\tau, \tau+1, \cdots)$;

$R_{n+1}^{\pi}(t, \cdot)$=time series of revenue from H_{n+1}^{π} (on and after τ time) $(t=\tau, \tau+1, \cdots)$;

ρ=social rate of discount $(0<\rho<1)$;

T_{n+1}^{π}=planning horizon.

If we consider the term of redemption (we set the maximum admissible value of added route by itself to be $T_{\max}$) to be planning horizon, T_{n+1}^{π} is determined depending upon the construction trajectory of H_n and

$$T_{n+1}^{\pi} \leqq T_{\max}. \tag{2}$$

is obtained.

Moreover, since the opportunity cost of construction funds for this added route must be covered and compensated from the national economic point of view,

$$\begin{aligned}
&\sum_{t=\tau}^{\infty} \frac{1}{(1+\rho)^{t-\tau}} F_{n+1}^{\pi}\left(t, {}^{\pi}P_1^{n+1}(t), {}^{\pi}P_2^{n+1}(t), \cdots, {}^{\pi}P_{n+1}^{n+1}(t)\right) \\
&-\sum_{t=\tau}^{\infty} \frac{1}{(1+\rho)^{t-\tau}} F_n\left(t, P_1^n(t), P_2^n(t), \cdots, P_n^n(t)\right) \\
&\geqq \delta \cdot C^{\pi}+\sum_{t=\tau}^{\infty} \frac{1}{(1+\rho)^{t-\tau}} \left\{M_{n+1}^{\pi}\left(t, {}^{\pi}P_1^{n+1}(t), {}^{\pi}P_2^{n+1}(t), \cdots, {}^{\pi}P_n^{n+1}(t)\right)\right. \\
&\left.-M_n\left(t, P_1^n(t), P_2^n(t), \cdots, P_n^n(t)\right)\right\},
\end{aligned} \tag{3}$$

must be satisfied; where

$P_i^n(t)$=time series of fare rate system for each route in the set of H_n (on and after τ time);

$F_n(t, \cdot)$=time series of the NEW (but, in terms of money) under the H_n $(t=\tau, \tau+1, \cdots)$;

F_{n+1}^{π}=time series of the NEW (however, in terms of money) under the H_{n+1}^{π};

δ=opportunity costs per unit of public investment funds $(1<\delta)$;

$M_n(t, \cdot)$=time series of management and operation costs for H_n (on and after τ time)

and, $P_i^n(t)$ is the solution for the next optimal problem:

$$\max_{\{P_i^n(t)\}} \sum_{t=\tau}^{\infty} \frac{1}{(1+\rho)^{t-\tau}} F_n\left(t, P_1^n(t), P_2^n(t), \cdots, P_n^n(t)\right), \tag{4}$$

$$\text{s. t.}\quad G_n(\tau)+\sum_{t=\tau}^{T_n}\frac{1}{(1+\rho)^{t-\tau}}M^n\Big(t, P_1^n(t), P_2^n(t), \cdots, P_n^n(t)\Big)$$
$$\leqq\sum_{t=\tau}^{T_n}\frac{1}{(1+\rho)^{t-\tau}}R_n\Big(t, P_1^n(t), P_2^n(t), \cdots, P_n^n(t)\Big). \qquad (5)$$

where,

$R_n(t, \cdot)$=time series of revenues from the H_n (on and after τ time) ($t=\tau, \tau+1, \cdots$);
T_n=the term of unredemption ($\leqq T_{\max}$).

Provided that there exist time series of ${}^{\tau}P_t^{n+1}(t)$ which satisfies (1) and (2) equations, then the route π can be contained in the set for selection (an element of which we call to be a *proposed additional route*) as an additional route to H_n for τ time. Conversely, in such a case that there does not exist time series of ${}^{\tau}P_t^{n+1}(t)$ which satisfies (1) and (3) equations simultaneously, the construction of this route π cannot be admissible except for depending upon the value judgement which transcends the efficiency criteria of national economic resource allocation and/or the criteria of the TPS as a principle of the SSAS (The so-called political route will be an example admitted by such a value judgement).

It can be understood that the relative magnitude of the *private usefulness* of this additional route is expressed according to whether the equation (1) is tight as a constraint or ont; and the *social usefulness* of this additional route is expressed according to the equation (3).

The condition in order for a set of plural routes to be included in the set for selection also can be obtained in a simlar form to (1) and (3) by developing same kind of argument as above.

The first approximation, here, to the dynamic investment criteria is intended to maximize the present total value of the NEW over the infinite period by allotting roles of control variable to the additional routes for each τ time and the time series of fare rate system of the NIES in which they are included under the constraint of the available funds for each τ time and the equations of (1) and (3) (or similar equations as them).

As the multiplicative effects and accumulative effects can be expected, even in the marginal sense, by constructing additionally plural routes (not single), then the proposed additional routes composed of plural routes can be expected to generate and bring additional benefits over the simple additive sum of *the additional benefits* derived from each proposed additional route composed of single route, which of course constitutes plural ones (the pure increases in the present total value over the infinite period of the NEW brought by constructing and utilizing the route concerned); however, on the contrary, funds constraint will be more tight. Therefore, to be more realistic, we should try the first approximation to the dynamic investment criteria (for example, by regarding all the funds over several periods on and after τ time as being available for τ time) on the assumption that we can substitute approximately plural routes by the time trajectory of construction of such a route as may continue to construct over several periods on and after τ time.

4. Economic Foundation for the Enforcement of the TPS

According to whether the equation (1) is tight or not as mentioned in the preceding section, it is to show degrees in the *private usefulness* of the NIES for the 'Japan Highway Public Corporation', and moreover make the internal subsidization (internal appropriation) from the surplus (black-ink) route to deficit one to be possible. Now, let the present total value of black-ink figures of the Toll-Pooling Accounting (TPA) over the planning horizon be S_n ($\geqq 0$), and the present total value of deficit figures of the Single Accounting (by route) of the additional route π over the planning horizon be D_π (<0), then

$$S_n + D_n \geqq 0\,, \tag{6}$$

That the equation (6) holds never fail to mean to make (1) hold. This means that the existing NIES is composed of relatively excellent routes judging from the managerial point of view, and the Japan Highway Public Corporation can give subsidies to (construction of) the deficit routes within the limits of S_n (we call this to be *Ante-Internal Subsidizing Possibility* (AISP)). However, now that this has the property as a 'subsidy', its management will have to be done by any rule. One of the 'Internal Subsidizing Rule of the Deficit Route (ISRDR)' based upon the efficiency of the national economic resource allocation is to impose the equation (3) as a constraint; by which the demand for construction of comparatively inferior route in the contribution to the NEW can be rejected at least, though it is so often done on the bases that the financial affairs are satisfactory at any rate and they will not run into red figures.

Usually, in the process of consolidation of the NIES, the transport route of which financial affairs are not so good, gradually, begins to be constructed on the bases of the quasi-dynamic investment criteria as explained in the preceding section, and S_n is to converge to the zero. However, this is the situation where the TPS exhibits mostly its special quality. That is, in such a case where the revenue of other routes grows greatly larger owing to the utilization of the route π even if there exist no funds enouth to subsidize D_π before the fact, and as it can be expected that the equation (3) never fails to hold in such a case, then there is a high possibility that the route π may be included in the set of selection of the additional route, admitting that the single accounting of the route π turns out to be red figures (and even if there exist no funds enough to subsidize it internally before the fact) (we call this situation to be *Ex post facto Internal Subsidizing Possibility* (EISP)).

In other words, it can be characterized that the TPS is intended to raise higher the national economic efficiency of resource allocation by making positively efficient use of these both Internal Subsidizing Possibilities. The significance of making efficient use of these may be divided into two broad classes: (i) to decrease the probability of risk that we may exclude a route the construction and utilization of which turns out to be very useful privately and socially though it may show drastic red figures in case of the single accounting, and (ii) to decrease the likelihood,

though it seems to be very high, that we may not be able to expect large amount of development effects or external economic effects including those in the Marshallian meaning as well, because of the relatively high priced fare rate system being adopted, even if such a route as mentioned above is not excluded under the SSASBR.

It is concluded that the social benefit of the national economic resource allocation owing to the TPS being adopted is definitely of positive values, in the case that such a '*local deficit & nationwide surplus*' route is included in the set of routes for selection and because that such national economic effects, therefore, will be of very large amount, in the meaning that even as to a route which were destined to be excluded from the finally selected set for the reason of becoming deficit according to the SSASBR, the construction of it can be approved under the TPS.

5. Effects of the TPS on Income Distribution

The qualitative proof on the non-inferiority of the TPS to the SSASBR in the Section 2 needs two qualifications of (a) and (b). Here, the former is considered; the latter will be referred to briefly in the next Section.

Though the property of the TPS lies in the making efficient use of the ISP, this apparently seems to be considered to bring forth rather wrong result on the income (re)distribution *among the users of the NIES*. That is, since S_n is the funds obtained from the H_n ($S_n>0$), there holds the view that it should be utilized for the construction and consolidation of the H_n. This will be supported by relatively weak value judgement. However, in the case that the present total value (we show this to be S^{π}_{n+1}) of the surplus obtained in the TPA, over the planning horizon, of the NIES (H^{π}_{n+1}) formed by the additional construction of a route π is at least equal to S_n, namely,

$$0<S_n\leqq S^{\pi}_{n+1} \tag{7}$$

holds, then the TPS is neutral in the income redistribution among the users relating to the Internal Subsidzing Funds, provided that we regard a part of S^{π}_{n+1} equivalent to S_n as a fund *for* H_n.

For the income redistribution effect among the users to come most into question is in the case that $S_n>S^{\pi}_{n+1}\geqq 0$ and/or the actual state of the 'local deficit & nationwide surplus' route may be occasionally attended with the increase in the burden of fare rate as for some routes in H_n, namely the equation:

$$P^n_i(t)<{}^{\pi}P^n_i(t) \qquad (t=\tau,\ \tau+1,\ \cdots), \tag{8}$$

holds as regard several i ($i\in\{1, 2, \cdots, n\}$). However, even such a case is not so important question if we take into consideration that the criteria for the route concerned being adopted only under the TPS lies in the property that the economic effects brought about by its construction and utilization are of the nationwide scale and amount as mentioned in the preceding Section. So far as the equations (1) and (3) are satisfied, there is a high possibility that there are large social economic

benefits enough to make even the existing users of H_n consent to appropriate S_n for the internal subsidization, or to approve a new increase in burden, which attribute to them. This possibility, indeed, becomes more large, *the smaller* S_n is (because, even in a situation where the internal subsidization from S_n is hard to be obtained, the 'local deficit' route can be adopted).

Most of such routes that will turn out to be of red figures if the constraint of the SSASBR is set lie in the developing area within Japan. As far as the equations (1) and (3) are satisfied, above all, the development effect or positive external economic effect which express-ways will bring about can be taken into consideration, the TPS has a profile of being approved by rather relatively weak value judgement as for the income (re)distribution, in the meaning that it is likely to induce the authority concerned to subsidize from relatively high income to low income region.

Though, sometimes related to this argument, there are similar arguments which advocate excluding the equation (1) and/or (3) from the set of constraints based upon the same relatively weak value judgement as above, at least it is a matter of course that these are not proper to the argument of whether we should adopt the TPS or not.

6. Institutional Basis for the Propriety of Adoption of TPS

Straightforwardly, it is a *practical* defect in the TPS that 'the so-called political route is liable to be constructed'; because it is out of question under the TPS that a route by oneself turns out to be deficit in itself. Nothing is not so 'strong supporter (?)' as this, for those who are eager to promote the construction of a political route. Particularly, in a case where S_n (>0) is of large value, the deficit route to be socially inefficient is apt to be constructed thoughtlessly and indiscriminately on the basis of its having capacity enough to bear a burden. It is the equation (3) measuring the social usefulness that checks this matter (the equation (1) is not tight in this case); however, it is very hard and difficult to measure the economic effect of a local route on a nationwide scale. There a loophole is ready to exist. Even if the equation (1) measuring the private usefulness is so tight ($S_n \fallingdotseq 0$), the route to be inefficient *privately and socially* is liable to be constructed by the same reason. Thus, it is understood that to adopt the TPS is intended to decrease the *risk probability* that we lose the possibility realizing the NEW in the more high ranking, at the expense of the risk bearing to deteriorate the financial contents of the Japan Highway Public Corporation (JHPC) (even to make it fall into the red). Contrary to this, the SSASBR is intended to decreases the latter at the expense of the former.

In the case that there happen to break out once the red figures in the accounts of the JHPC internally with no resolution yet in sight, How should we resolve this by economic policy? How should we establish the management and operation system so as to apply the TPS in conformity with the original model more normally and exactly including the 'exact' resolution of measurement problem (or up

to what extent have this matter been resolved)? It is dependent upon the resolution prepared for these two questions as mentioned above which we should take into account and argue more thoroughly, and consequently which risk we should avoid.

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