Financing Infrastructure over Time

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TRB Submission July 20, 2000
November 13, 2000 Revision
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ABSTRACT

This paper investigates the problem of financing infrastructure over time when the number of users also changes. The problem is confronted in many fast growing communities desiring to coordinate the timing of infrastructure and development, yet still achieve economies of scale where they exist. The temporal free rider problem is defined; whereby the group that finances the construction at a given time is not identical with the group that uses it. The continuous recovery method, which effectively establishes a property rights framework for infrastructure is described. Continuous recovery enables existing residents to be appropriately compensated by new residents, independent of the number of new residents who ultimately arrive. The system is illustrated and compared with practice in a case that uses a non-continuous cost recovery system.

Key Words: Infrastructure Financing, Impact Fees, Free Riders, Bonds, Pay-as-you-go Financing

INTRODUCTION

Local jurisdictions must balance present and future needs with costs when financing infrastructure. When a fixed piece of infrastructure is funded and built by one group, and then a new group comes in and uses it without paying, there is a free rider problem. When one group comes in and borrows money to build infrastructure, and another group is held liable, there is also a free rider problem. The extent of the problem depends on site-specific circumstances, the nature of financing, and the placement of the tax burden. This paper will consider these factors and evaluate suggested solutions.

In the past two decades, many localities have levied impact fees to finance new and expanded infrastructure (Altshuler and Gomez-Ibañez 1993, Bauman and Ethier 1987, Downs 1992 Lee 1989, Nelson 1989, Popper 1988). The fees are designed to be associated with the "impact" of the development on public services. The impacts include the full gamut of publicly provided services, including roads, sewers, schools, and parks. While development has generally been held responsible for constructing on-site public services, off-site facilities are often addressed by impact payments. Some communities have adopted value capture districts to tax adjacent development for the benefits associated with new transportation infrastructure (Stopher 1993). Others have implemented stringent growth management regulations only weakly tied to financing (Levinson 1998a, Pollakowski and Wachter 1990).

The underlying need for taxes on development arises due to the financing mechanisms used to pay for infrastructure. Suppose a community has adopted "pay as you go" financing and pays outright for a road. When a residential or commercial development comes along, it doesn't pay the one-time fixed cost of the road, which has already been absorbed by the earlier taxpayers. Failure to recover funds from the development creates a free-rider problem. Foreknowledge of future failure to recover those funds may discourage the investment in the first place, leading to under-investment. Cost recovery techniques include user charges and impact fees as well as specially designed policies. Alternatively, a different initial financing system, such as bonds (sometimes called "pay as you use"), can be used to help alleviate the problem.

Often a piece of infrastructure can be described by a "U-shaped" cost function. Average fixed costs decline with additional users, but average variable costs rise. At low demand levels, average fixed costs dominate, at higher demand, variable costs are more significant. The appropriate financing mechanism depends on whether costs are falling or rising, while the same system may exhibit different behaviors at different times. When average costs are rising, marginal cost pricing can pay the costs of infrastructure. Unfortunately, in practical terms, it is unlikely that road pricing will be widely implemented in the near term due to technological difficulties in exclusion and monitoring, as well as political problems in implementation. Further, with rising average costs, existing residents have little incentive to encourage new users of the infrastructure, existing residents may insist on significant compensation. When average costs are falling, each additional user has little impact on existing users. Yet those existing users who paid for the one-time fixed costs would certainly prefer to be compensated by new residents who constitute additional users of the infrastructure.

Financing is further complicated because infrastructure is often indivisible; roads, for instance, are built in discrete units. Finally, whether the jurisdiction is open (developers have alternatives locations) or closed (developers can either locate in the jurisdiction or not develop) greatly influences the outcome of negotiations about what charges are paid.

The analysis in this paper will be similar in some respects to that put forward in previous work by the author (Levinson 1998b) that analyzed tolling along a road connecting adjacent jurisdictions. The foremost difference is that while two groups in time (new and old development) are like two groups in space, the earliest group always moves first, without knowing exactly what the later group will do. Though the first mover acts with uncertainty, the later group knows exactly what the early movers did.

Although this paper focuses on urban and suburban arterial streets to provide concrete examples, financing in time affects many types of facilities. Arterials serve the function of enabling both access and movement, are not easily excludable, and are often maintained by city or county governments. Thus, they are unlike neighborhood collector and distributor streets built by the developer of a subdivision - which only local traffic would use. They also differ from major inter-city highways, which are operated by state governments (in the American context) and are often designed as limited access facilities. Often arterial streets are financed from taxes or developer exactions.

In an ideal world, it would be possible to scale roadways so that they can be added as appropriate by development. There are several practical difficulties with this approach. The first problem is the indivisibility of roads. At best, streets can be built a lane at a time, but a half-lane seldom makes sense. While at large scales, the indivisibility problem becomes relatively minor, in smaller jurisdictions it remains considerable. A second difficulty is the timing of infrastructure deployment; the cost of congestion rises suddenly compared with the decline in the average fixed costs of infrastructure. To be “optimal” a community must have a great deal of foresight about when a particular level of congestion will occur and have a road ready to be opened at that point. A third issue is the cross-group use of roads; new residents may drive on existing roads, while existing residents may use the new roads. However, these uses may not be equal.

An alternative to impact fees while still recovering costs is to, in effect, "rent" the network. This can be accomplished, for instance, by paying for a facility with borrowed funds. Because the community pays annual installments, as the size of the community grows with development, the average cost of the infrastructure for both new and existing residents drops. This encourages the right amount of investment. The downside to renting is that the excess cost of renting may exceed the revenue that can be gained by investing the initial capital elsewhere.

Another alternative is to have an explicit recovery policy in place. At least two kinds of recovery policies come to mind. The first allocates in advance the amount development must pay to the community to recover expenditures of fixed costs. The main difficulty with this approach is its reliance on forecasts, which may or may not materialize. The second, “Continuous Recovery” policy, dynamically adjusts the charge development must pay, but directs that payment to compensate existing residents for earlier payment. Existing residents can be thought of as owning the facility.

This paper proceeds first by outlining a scenario commonly found, where infrastructure, with a high fixed cost but low variable cost, must be built to support existing and new residents. Pay as you go, bond financing, and impact fees are compared, and then a continuous recovery approach is developed. While economic theory is geared to using marginal cost pricing, this paper describes the intelligent use of an average cost approach for cases where marginal cost pricing does not recover sufficient revenue. The issue of relative bargaining power between an existing community and a developer is discussed as a limiting factor to this approach. An example is presented comparing the continuous recovery approach with the cost recovery approach found in some communities for financing water and other infrastructure systems.

OLD VERSUS NEW

Consider this situation: A large community has built a section of roadway, paid for by property taxes. A residential development nestled within or adjacent to the previously existing community is constructed. The landowners of the development site paid a negligible share of the cost of the roadway, since their land was undeveloped at the time of construction. No new roadways are needed to support the development. How much should the development pay to use the existing infrastructure? To whom should the check be written?

Conventional economic theory says that it is efficient that development pay its marginal cost, even if marginal cost pricing does not recover the fixed cost of building the infrastructure in the first place. If the development only pays its marginal cost and average costs are falling, it is free riding on the fixed assets constructed by the previously existing community. Existing residents may not find this outcome fair or desirable. Anticipating this outcome, the older community may attempt to do something to prevent it from happening in the first place, by adopting some regulatory mechanism.

This brings out the first issue: what are the expectations involved? Does the existing community have an expectation (such as a law on the books) of being reimbursed when it decides to expand a capital facility, or does it lack that expectation until after the facility is constructed? That expectation depends on whether a policy has been adopted, and as importantly, when that policy was adopted. If the policy was adopted prior to the construction of the existing infrastructure, there is an expectation of recovery (point A on the first row of Figure 1). However, if the policy came after the existing infrastructure was built, but before any new development, then recovery is an added bonus to the existing land owners, who still may be able to exact it from new development (point B). While, if the policy arrives after the development, it has no effect (point C). However, if development leads a decision to build infrastructure, then it is likely both the pre-existing community and the development will be assessed at point D or point E, as shown on the second row of Figure 1. This is because separating out the groups after a development is approved and constructed is difficult (the constitution prohibits ex post facto laws). This case, like point C above, places a greater burden on the community than would have been required prior to the approval of the development.

PAY-GO, BONDS, AND IMPACT FEES

Three basic financing schemes can be considered, with numerous variations. The first is pay as you go (Pay-Go), which requires that a facility be paid for when constructed. In the absence of a recovery procedure, the payment falls on the residents at the time of construction. The second is some sort of bond financing, wherein the payments are spread over time, and fall on those in residence at the time of the payment. Bond financing adds an interest charge for the cost of capital. The total costs of bond financing may exceed the total costs of pay as you go financing, depending on a comparison of market interest rates and the return to opportunities available for spending capital. A third financing mechanism is an impact fee, which would be a lump sum charge imposed for new infrastructure on new development

These financing schemes for two classes of infrastructure have incidence on the two classes of users as shown in Table 1. In the pay-go system, all new infrastructure will have to be paid for by everyone, not just the development. A growing community where new residents are expected to be numerous compared with earlier residents will prefer re-financing old infrastructure with bonds, but for new infrastructure the computation is more complicated. An assessment must be made about future development as well. If the development is the last one a community will see, pay as you go might be preferred to bonds (to reduce future interest costs). However, if the development is simply one in a long string of oncoming development, bonds have advantages over pay-go. With bonds, the base over which payments are made will continue to be expanded (and the per capita payment will decline over time).

This situation can be formulated as a game, with the objective for players (community, developer) to minimize their own costs given a certain infrastructure deployment. This is a one-time game, while the decisions may recur; they do so with different player sets. If existing residents choose the financing means for old infrastructure and the developer chooses it for new infrastructure, then (re-) financing both old and new infrastructure with bonds is generally a stable equilibrium. A different solution may result if there is little future growth or the costs of bonds are large relative to pay-go. However, if the residents set the rules under which infrastructure are financed, then old infrastructure would be paid for with bonds and new infrastructure would be paid for by an impact fee on development. (And if developers set the rules, then old infrastructure would be pay-go and new infrastructure pay-go or bond).

So, inter-temporal equity in terms of allocating costs to those who cause them, efficiency in terms of internalizing costs of infrastructure to those who benefit from it, and stability all argue for bond financing over pay as you go for financing capital facilities. The primary downside is the additional costs associated with interest payments.

CONTINUOUS RECOVERY

It should be possible to develop a mechanism for achieving the benefits of inter-temporal equity and efficiency without the costs associated with borrowing on the open market. This is continuous recovery, which effectively makes the existing residents the owners of a "capital facility club", which new residents can join by paying their share of the cost to the earlier members[1].

As shown in Figure 2, development (q) pays the average cost of infrastructure (c) to existing residents (Q), this compensates old residents (Q) for their "excess" payment. In this case, development pays what it should in terms of “second best” pricing, it just pays it to the existing residents. If this doesn’t happen, old residents are paying more than they should (their excess payment), since the recovery of costs was anticipated, and thus internalized in property values. The relationships are expressed below:

$$(Q + q) * c = Q * C \quad (1)$$

$$C = T / Q \quad (2)$$

$$c = T / (Q + q) \quad (3)$$

where: T = Total Fixed Cost

C, c = average fixed cost of infrastructure before (C), and after (c) development

Q, q = existing population (Q), new population (q)

However, the actual (out-of-pocket) cost of allowing q to develop given Q is zero if average costs are falling, so anything q contributes bails out Q. This situation applies to the case where the recovery policy is imposed after the existing residents pay for the capital facility, but before the development is constructed (as opposed to before both old and new development). The property right to recover the money invested in the capital facility is not as strong in this case as when recovery was assumed before the initial decision to construct the infrastructure. One might suggest that there is a welfare loss with recovery.

In this case, the welfare loss (demand not realized because it is priced) is denoted by the shaded triangle in Figure 2. Here, no individual would be harmed in the short run by permitting extra development (as we only have fixed costs). This welfare may not change the motivation of the original residents, as the loss accrues not to them, but to some other set of individuals (potential new residents). If the capital facility was already paid with no expectation of recovery and has no marginal costs to use, why shouldn’t additional users be able to free ride? How does free riding harm anyone? Charging for use without an expectation of recovery is “unfair," just as being unable to recover costs when there was an expectation that one could. However, "unfairness" may to lead inefficiencies. These inefficiencies include underinvestment or lagging investment over the long term. Residents may choose not to build in advance if unfairness is perceived. Furthermore, this kind of "cheating," exploiting a resource without compensation, will eventually lead to a loss of confidence in the system.

BARGAINING

While the right to permit development may always reside with existing residents, the actual ability of residents to impose costs on development depends on the respective bargaining strengths of the community and developers. Perhaps the most important indicator of bargaining strength is the degree of monopoly power the residents of the existing jurisdiction have. That depends on the choices available to a developer and the potential new residents the developer represents.

In a “closed city” the entire analysis area is contained within one governmental unit, so the existing residents have very strong bargaining power. New residents (developers) can either pay what existing residents ask or not locate there. A closed city may be an isolated community, or a strong regional government (with growth controls) giving a spatial monopoly to existing residents at the expense of potential residents.

In an “open city”, new residents or developers can play jurisdictions off each other, if one charges too much, another may undercut it. In an open city, relative bargaining strength resides with developers, who can drive development exactions down. Since something is better than nothing in terms of recovering fixed costs (when there are declining average costs), the existing community may accept less than its full fair-share cost recovery from a new development.

In addition to the open city / closed city distinction, other factors may play into bargaining about recovery. These include other positive and negative externalities of development, in particular tax base changes, demands on public services, accessibility benefits and congestion costs. If the existing residents receive a positive net benefit from the development, the amount they constrict the development should be less than if there is a negative net benefit (X). Similarly, if the development achieves economic profits (Π), then the existing community may try to exact some share of those profits in exchange for permission to develop. The resulting charge will range between a subsidy to development up to the amount of a positive net externality, to a charge of up to the economic profits of the development. More precise values than this depend on market conditions and the number of competing jurisdictions and developers.

Table 2 is the payoff matrix to user classes (community, developer) under two conditions of recovery from the community and two responses from a developer. The actual amount of the payment ranges does not exceed Π, but must exceed X. If the externality is positive, then the payment may be negative. The precise amount is indeterminate from this analysis.

EXAMPLES

There are a number of cities with capital recovery (or recoupment) fees for water and sewer, among them (discovered by the author through internet search) Austin TX, Chelmsford, MA Chesterfield County VA, Concord NC, Conway SC, Dunedin FL, Gurnee, IL, Houston TX, Loveland CO, Montecito CA, Pooler GA, Round Rock TX, San Jose CA, Santa Clara, CA and Calgary Canada. There is also a software package automates the process of calculating the rates (Ratemod 2000). Capital recovery is also becoming a significant issue in electricity deregulation; particularly concerning who will pay for existing expensive generation plants (so-called "stranded" costs). However, the use of capital recovery charges does not seem prevalent in other infrastructure categories.

Loveland Colorado is perhaps the most widely recognized example of a capital cost recovery impact fee (Heath et al 1989, Nicholas, Nelson, Juergensmeyer 1991).

Impact fees comprise 5.8% of the city budget, while user fees are 9.1% and utilities are 46.3% (Loveland 2000). Unlike conventional impact fees, which are used to expand facilities, the recovery fee allows development to buy into existing excess capacity provided by the community. A sample calculation for a library facility in Loveland using their approach and a comparison with the proposed Continuous Recovery approach are given in Tables 3 and 4.

Table 3 illustrates the Loveland policy as applied to a library, ignoring corrections for excess capacity, external funding, or splits between residential and commercial development. The total capital cost of the facility is allocated proportionately to existing and future households. The capital expansion fee is simply the share allocated to future households divided by the number of those households. The continuous recovery policy (Table 4) on the other hand does not have a single fee. Rather, the fee depends on the number of units that have actually been developed. So, for instance, if only 5,000 additional housing units are constructed (rather than the 14,700 forecast), the cost per unit for those 5,000 will be higher ($187 vs. $121). As additional units are constructed, the earlier units are given rebates. Small differences in numbers between Tables 3 and 4 are due to rounding error in the original Loveland example.

There are several differences between the Loveland and other real-world examples and the proposed continuous recovery system. The first difference concerns whether individuals or the community is repaid by the system. Existing capital cost recovery approaches fail to return the funds directly to the residents who paid for it. That is, they are, or are analogous to, a debt financing system for bonds rather than a community owned capital facility club. Second, the choice of basis over which to estimate the fees is critical. Either a historical basis (the cost to actually build the facility for which excess capacity is being sold) or the cost to replace the facility (minus depreciation) in current dollars could be used. Loveland assesses based on replacement cost. However, the use of a replacement basis, while certainly appropriate for new or future construction, may result in a profit to existing residents or the community as a whole when the capacity has already been built. Third, the Loveland program keeps the fee fixed, a true continuous recovery program as outlined in the paper would vary the fee over time based on the number of actual users. Loveland's program requires forecasting the ultimate number of users, and then allocates costs accordingly. Should the forecast be optimistic and not all the new residents materialize, then the original residents of Loveland will have overpaid (if Loveland does not use bond financing).

SUMMARY AND CONCLUSIONS

When infrastructure needs to be financed with taxes rather than user fees, the issue of which class of citizens pays for the infrastructure is still not resolved. A properly designed financing system is still required in order to have an equitable distribution of the burden while producing efficient infrastructure. The financing system must operate within the confines of an institutional structure that attributes the ownership of the infrastructure to those who paid for it, and does not allow use without buy-in.

The continuous cost recovery system suggested here is an improvement upon top-down financing allocation systems that rely on the realization of forecasts to achieve an equitable burden. If the forecasted levels of development are not reached, the existing residents are stuck holding a larger payment than are those who moved after the charge was imposed. If property rights to road use are placed in the hands of existing residents, then a mechanism for recovering fixed costs is a necessary feature of a politically viable infrastructure financing system.

The argument was made that an inter-temporal equity policy is necessary to encourage an efficient level of infrastructure investment. There are several mechanisms to achieve inter-temporal equity, including bond financing or an explicit policy of recovery with pay as you go financing. These procedures do not supplant impact fees to pay for congestion or facility expansion. Rather, they supplement the marginal cost approach to recover fixed costs when marginal costs are zero or falling.

This paper dealt with residential development. However, the attribution of transportation infrastructure costs to residential or commercial development is very much like the argument about taxing income or sales. A trip has two ends, which end pays what share of the infrastructure cost of the trip is in many ways arbitrary. It would be a simple extension of this process to allocate a share of infrastructure costs to different sectors (office, retail, industrial, other, residential), much as is done in the Loveland system. The extent of pass through of costs from development to consumers depends on the relative competitiveness of markets. Nicholas et al. (1991) discuss the issue concerning housing costs, other costs should be similar.

The actual outcomes in terms of the selected financing mechanism and the amount paid rests critically on the institutional assumptions of a “right” of access to infrastructure for a new development or a “right” to prevent access by the existing community. It further rests on the relative bargaining power, determined by the alternatives available to a developer or potential new residents in terms of sites to build or locate in neighboring communities. Many of the actual results are indeterminate within a core range of values. In a city where developers have bargaining power, charging more than the market will bear will eliminate the possibility of any recovery.

The application of this approach in a community surrounded by non-adopting jurisdictions is limited by its bargaining power. In the short term, it may not be possible to recover 100% of fixed costs if neighboring jurisdictions are providing irrational development subsidies. In the long run however, a sound financing system and strong public services should be an attractive amenity to new residents and commercial development. Soundly financed services should shift the demand curve, which will increase the community's relative bargaining power, offsetting partially or entirely the short-term problem of neighboring communities subsidizing development.

END NOTE

1. As a practical implementation of this idea, we can think of forming an infrastructure club. To begin, assume that infrastructure is collectively indivisible, so that no weighting of the cost-share infrastructure by use would be made. All existing households

would be grandfathered into the club, but all new households would be required to pay a membership fee to the existing members. The fee would be proportionate to

$$I_n = \frac{T}{Q+q}$$

where:

I_n = Fee new households must pay to buy into infrastructure club
Q = Population of existing households (excluding new households)
q = Total number of new households
T = Total fixed cost of existing infrastructure attributed to households
The fee (I_q) would be rebated to existing households periodically (as a tax refund for instance). A similar model could be applied to commercial development.
Thus at the end of a time period, each existing household would be paid J_Q:

$$J_Q = \frac{\sum_{q=1}^{q} I_q}{Q} = \frac{\sum_{q=1}^{q} \frac{T}{Q+q}}{Q}$$

However, new development might also bring with it additional infrastructure. This "payment in kind" would need to be credited. We can, as above, calculate a fee that each existing household would have to pay to each new household to compensate it for bringing new infrastructure to the table

$$I_Q = \frac{t}{Q+q}$$

where:

I_Q = Fee existing households must pay to compensate new development for providing infrastructure to add to the infrastructure club
t = Total fixed cost of new infrastructure attributed to residential development
Thus at the end of a time period, each new household would be paid J_q:

$$J_q = \frac{\sum_{Q=1}^{Q} I_Q}{q} = \frac{\sum_{q=1}^{Q} \frac{t}{Q+q}}{q}$$

Thus the net payment (K_q) for each new household would be:

$$K_q = I_q - J_q = \frac{T}{Q+q} - \frac{\sum_{Q=1}^{Q} \frac{t}{Q+q}}{q}$$

And the net compensation (K_Q) for each existing household would be

$$K_Q = J_Q - I_Q = \frac{\sum_{q=1}^{q} \frac{T}{Q+q}}{Q} - \frac{t}{Q+q}$$

While this fee is paid all-at-once to existing households, new households might see it added to their mortgage. Clearly this is a simplified model, extensions would include spatial differentiation to account for different usage of different facilities by different areas. In each period, the existing population (Q) would grow by the number of new households (q).

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Table 1: Cost Incidence

		New Infrastructure		
		Pay-Go	Bond	Impact Fee
Old	Pay-Go	[F/Q + f/(Q+q), f/(Q+q)]	[F/Q + r/(Q+q), r/(Q+q)]	[F/Q, f/q]
Infrastructure	Bond	[(R+f)/(Q+q), (R+f)/(Q+q)]	[(R+r)/(Q+q), (R+r)/(Q+q)]	[R/(Q+q), R/(Q+q)+ f/q]

note: [existing residents payment, new development payment], for simplicity, assume that new development follows immediately after infrastructure (re-) financing, so that bond payments for old infrastructure are borne proportionally by old residents and new development

where: R, r = net present value of future bond payment for old (R) and new (r) infrastructure
F, f = fixed cost for old (F) and new (f) infrastructure
Q, q = existing population (Q), new population (q)

Table 2: Bargaining

		Developer Do Not Pay	Pay if Required
Community	No Payment Required	[0 - X,Π]	[0 - X,Π]
	Payment Required	[0 , 0]	[Payment - X, Π - payment]

X = net negative externality
Π = economic profit to new development
if Payment < Π and Payment > X then development will occur with payment

Table 3: Loveland Capital Expansion Fee

Category	Loveland
A. Total Capital Cost	$3,354,000
B. Replacement and Betterment Cost = A * Q/ (Q + q)	$1,571,300
C. Future Capacity in Units	14,700
D. CEF Fee = (A - B)/C	$121

source: adapted from Table 13-2 Nicholas et al. (1991) and author's calculations
note: Q, q = existing population, new population (32,700, 37,100) in persons (at 2.53 people per household, ~ 12,900, 14,700 households respectively)

Table 4: Continuous Recovery

Category	Continuous Recovery
A. Total Capital Cost	$3,354,000
B. Initial Cost per Household = A / Q	$260.00
C. Fee for First New Household = A/(Q+1)	$259.98
D. Fee for 5,000th New Household = A/ (Q+5000)	$187.37
E. Fee for Last New Household = A / (Q + q)	$121.52
F. Total Amount Paid (before Returns)	$2,550,944
G. Total Amount Returned to q	$764,575
H. Total Amount Returned to Q = Net Total Amount Paid by q	$1,786,370
I. Amount Recovered by Q per household = H/Q	$138.47
J. Net Payment by Q = B - I	$121.52

Figure 1: Timeline of Recovery Policies

Infrastructure Leads Development	Community ->	[A] ->	Infrastructure ->	[B] ->	Development ->	[C]
Development Leads Infrastructure	Community ->	[A] ->	Development ->	[D] ->	Infrastructure ->	[E]

Figure 2: Illustration of Welfare Loss