Cost-Oriented Methodology for Short-Range Transportation Planning

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A transportation planning methodology is proposed that is more adaptable and responsive to short-range issues than is the existing transportation planning process, which was designed as a long-range methodology. The suggested planning process (a) approaches conclusions in an iterative manner, (b) has flexibility in the ordering of steps in the procedure, and (c) requires fewer data. Although demand analysis constitutes a key component in the methodology, emphasis is on a comparative cost impact evaluation framework, in contrast to a demand forecasting approach. The I-66/Metro corridor near Washington, D.C., is used to illustrate one cycle of the analysis.

Transportation planners are currently struggling with a methodology developed for long-range planning and not easily adapted to short-range planning problems. A primary difficulty seems to be the inherent linearity of the methodology, although attempts have been made to incorporate feedback lines into the analysis. Compounding this with the concept of comprehensiveness (5) results in a process that is cumbersome, awkward, and unreliable in addressing the specific issues of short-range planning.

The strategy presented attempts to strike a balance among several objectives: the need to handle complex interactions, the desirability of a methodology that can be disaggregated piecemeal to suit the particular application, the need to improve communication between the technical and political components of the planning process, and the desirability of streamlining transportation planning analysis as well as reducing its cost. More particularly, the methodology is (a) iterative in that it approaches a solution by cycling and recycling over the major components, (b) flexible in that the ordering of steps is not predetermined, and (c) parsimonious in that it uses the least amount of data that will support a policy decision.

Although some previous efforts (8, 11, 27, 29) have applied nonstandard approaches to the analysis of transportation issues, an alternative synthetic framework has not been developed. Mechanics of the methodology described below are illustrated by using the I-66/Metro corridor in northern Virginia.

FACTS, TARGETS, AND REQUIREMENTS OF THE IMPACT EVALUATION FRAMEWORK

A short-range impact evaluation framework is shown in Figure 1. Input parameters include base wage rates, purchase price of vehicle, fuel prices, and construction costs; service environment factors are the conditions affecting wear and tear and characteristics of the population served. Demand, service quality, pricing, and capacity are the major areas that may require iteration and are, for the most part, variables controlled or influenced by the public sector. A wide variety of unit costs including total deficits, deficit per passenger carried, trip cost per passenger, external costs, and long-run average cost provide the primary basis for evaluation. Travel time for the user can be entered as a cost or as a measure of quality.

Operationally, the analyst begins by listing salient facts (e.g., capacity of existing road network, price of gasoline) and adds a list of targets (minimum levels of service, desired modal split, maximum cost per trip, given vehicle capacity) until enough information has been assembled to calculate requirements (additional capital investment, occupancy factors, feeder systems, levels of operation). Any of these may be reordered, either between different problems or within different cycles of the same problem. Modal split, for example, can be regarded as fact, target, or requirement; the price of gasoline may be a fact today but a policy variable tomorrow.

Unit Costs

Under the proposed methodology, unit costs are the primary evaluation measure. This means not that benefits are ignored or that cost minimization is the decision criterion but that evaluation falls into one of the two following types:

1. For a given level and quality of service, costs

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should be minimized. This is a form of cost-effectiveness analysis, in that minimum costs for various levels of service can be compared and evaluated.

2. Benefits are evaluated in terms other than monetary units. Travel time savings, pollution reduction, energy savings, and reduction of waiting time can be quantified to whatever degree seems reasonable, but it is not necessary to force a dollar value on the results. If a good estimate of social value is readily available, of course it should be used.

This decision criterion, then, weighs social costs against a list of benefits, many of which are quantified and some of which are priced. The technical analyst can often make strong recommendations based on findings and expert judgment, but in most instances the decision is a political one; the planner should not attempt to subvert that process by providing a technical conclusion.

Choice of the most suitable unit cost is a difficult one, and often several will be needed from the multiplicity available. Figure 2 shows that possible unit costs range from cost per passenger-kilometer to costs per year. Not shown in Figure 2 are the various groups for whom a cost figure may be of interest: users, general taxpayers, transportation authorities and commissions, local and federal governments, and so on. There is no a priori best unit cost measure and no definitive list of impacted groups; at some point, however, it will be necessary in each problem situation to determine units and groups of interest, since the analysis has to be constructed with those in mind.

Input Parameters

None of the variables under consideration in the proposed methodology is purely exogenous, i.e., independent, but those listed under input parameters are the closest to being "facts." Items such as the base wage rate, vehicle lifetimes, and energy prices may vary by locality, while items such as vehicle cost, gasoline consumption rate, discount rate, and vehicle capacity (9) may pertain to the United States generally.

These basic input parameters were used in a sizable amount of literature on the construction of simplified cost functions (1, 2, 3, 6, 7, 10, 12-26, 28). Items such as construction cost per lane-kilometer, labor-hours per vehicle-hour in service, and vehicle-kilometers (or hours) per year per vehicle have been found to be stable enough or to vary systematically enough to provide useful rules of thumb. Techniques of statistical estimation, budget allocation, and theoretical relationships have been used to construct cost functions.

Service Environment

Attributes of the environment in which the transportation service must operate affect both the demand and the quality of service, for a given input of resources. From the other perspective, a difficult set of operating conditions—congested streets, harsh climate, incompatible user groups, high crime areas—will increase the cost of providing a given level and quality of service. Very little structural understanding of these interrelationships seems to have appeared, and the subject area constitutes an unfortunate research gap.

Demand

Constructing a complete demand function, or schedule, for all types of service, price combinations, location patterns, and the like is an extremely difficult task empirically and would be about as empty an exercise as is forecasting detailed land uses 20 years in the future. Most of the detail is not needed for planning purposes anyway.

So we are left making point estimates of future travel demand. These estimates can be greatly improved, however, if it is recognized, particularly in the short run, that price and service elasticities are valuable analytic tools, even if correct or even good pricing is not followed. Many problem situations require that alternative service levels and user charges be compared, and demand estimates should be responsive to these choices.

Capacity and Use

A given set of available resources (labor, rolling stock, right-of-way, materials, management) represents a capacity to offer service, which can be translated into vehicle-hours, vehicle-kilometers, peak seat capacity, or other measure of intermediate output. With a certain number of drivers and buses, for example, some number of bus-hours of service per day can be provided. The speed of this service then depends on the type of terrain, quality of the streets, congestion, number of stops per kilometer, and number of passengers per stop, among other things. Vehicle use is a function of peaking conditions and the amount of deadheading that is acceptable, while average occupancy is a function of available capacity and service demand.

Service Quality and Pricing

Based on the operating environment and the available capacity, actual characteristics of the service provided can be estimated. The user is not interested in the number of vehicles in service, the amount of congestion, the hilliness of the terrain, or the speed of the vehicle, except insofar as these determine the travel time, comfort, security, and other qualities that affect choice of trip, mode, and time. Service quality is the aspect of the supply side of the equation that interacts with the demand side, to set an equilibrium. Pricing, in this context, is limited to the impact of user changes on service consumption.

Standard mode choice analysis starts with a list of service quality characteristics for each mode and allocates to each mode a share of total demand. For some situations it may be more desirable to approach the question from the standpoint of what modal split would be necessary to achieve target occupancy and cost levels and what manipulation of service characteristics will be necessary to achieve that modal split. The object is to be able to do it both ways.

AN EXAMPLE: I-66/METRO CORRIDOR

The study corridor lies in northern Virginia in the Arlington, Falls Church, and Fairfax County suburbs of Washington, D.C. (Figure 3). Two major corridors, I-66 and Va-7, almost come together at I-495, the Capital Beltway; the remaining 16 km (10 miles) or so of the corridor into the District currently rely on a number of arterial highways. A summary of a first-cycle analysis is presented below.

Service Environment

Washington is a strongly core-dominated metropolitan area, and the I-66 corridor is one of several suburban commutersheds for the District. Arlington contains some apartment buildings, but the general pattern is one of single-family, townhouse, and other moderate- to low-density residential development: Population density declines from about 4600 persons/km² (12 000 persons/mile²) at the inner end to about 1500 (4000) at a distance of 9.4 km (15 miles) out.

Demolition and relocation are not major problems inasmuch as most of the right-of-way was acquired some time ago. Currently, I-66 runs from the western edge of Fairfax County to the Beltway, so the traffic in the corridor is primarily commuter (not intercity or freight) vehicles. A profile of existing traffic during peak periods shows that the volume at the Beltway is slightly greater than that crossing the Potomac; in between, volume, which is siphoned off to office concentrations in Arlington, reaches a maximum. Hence, the Beltway is taken as controlling, for design purposes.

Input Parameters

Cost and capacity factors to be used for planning are given in Table 1, in their most natural units. For comparisons to be valid, costs must be stated in constant dollars (1975, in this case) and must be translated to a common unit of time.

Demand

Based on local estimates (4) of suburban development in the Va-7 and I-66 corridors outside the Beltway, 1985 peak-hour one-way trips at the screenline will be 45 000 persons (Table 2). The volume at present is 17 600 on a network that can carry about 9000 vehicles in the peak hour.

The estimate of future trips is subject to considerable error (no matter how precise or sophisticated the method) and is also influenced by public policy. Given the short-range framework applied here, it is assumed that

1. Impacts of changing land use patterns will be small on the aggregate forecast and
2. Total daily person-trips for work purposes will not be strongly affected by supply variables or pricing (instead, these variables will influence time of travel, mode, and occupancy).

Although the probable impacts of alternative land use patterns and supply side variables will certainly be substantial, they are less than the error inherent in the aggregate forecast itself.

Capacity

In the example, the major choices are the peak capacity to be provided on transportation facilities and the balance between modes. Only the line-haul system is considered explicitly, and the problem of how to accommodate a large number of additional vehicles in downtown Washington is shunted aside. The intent of this strategy is to restrict the analysis of downtown distribution problems to those alternatives that look good from a line-haul perspective.

Alternatives

1. Freeway. All additional trips are carried by automobiles, at 1.4 persons/vehicle. If we assume 2000 vehicles/hour/lane, 11.6 additional lanes of freeway would be required in the peak direction.
2. Metro. A surface rail rapid transit extension is used to full seated capacity, and additional trips are carried on buses. The excess demand left by a two-track Metro line will require about 160 buses loaded at 100 percent of seated capacity. In addition, transfer facilities from other modes to Metro would have to be developed.
3. Bus on busway. Same as alternative 2 but with a busway substituting for the rail line.
4. High occupancy. If no additions are made to the physical capacity of the network, the total number of peak trips can still be accommodated by increasing average vehicle occupancy. If we assume that automobile occupancy averages 3.0, vans average 8.0, and buses average 50 passengers at the Beltway and also that vans and buses are mixed equally in number, then 346 each of buses and vans would be needed. The remaining 8308 vehicles would be automobiles.

Not considered in these alternatives are possibilities of reducing the total number of trips, reducing the number of peak-hour trips by spreading the peak, using smaller vehicles, or developing systems not currently in general use in the United States. If all of the four alternatives prove unacceptable, then other alternatives might be sought; combinations of the above alternatives can be constructed once it has been determined which ones to emphasize.

Quality and Pricing

As a target, the objective is to maintain or improve existing levels of door-to-door service. What this objective means in practice and in detail will have to wait for a subsequent cycle in the analysis. It is assumed that each line-haul service would be adequately supported by feeder collection and distribution systems so as to achieve the mode splits given in Table 3. This assumption is not neutral between modes, of course; CBD distribution, for example, is much better on a subway system, while other core work trips can best be handled by express bus.

The central question of quality in the I-66 example is how and whether different travel patterns and modal splits can and will be achieved such that individuals will be provided a range of choices. Pricing incentives (e.g., monthly passes) and disincentives (e.g., elimination of free parking downtown) as well as physical constraints (car pooling and bus lanes that are adequately policed) can accomplish a great deal but may, at the same time, generate strong opposing pressures. Because these issues depend to a large extent on where the political will and the political muscle are located, analysis can only provide the options, not the answers.

Unit Costs

Because of the way the I-66 example has been constructed, both total trips and trip quality are assumed constant between one alternative and another; hence, user benefits and the effectiveness of each alternative are the same. Although this need not be the case, in the example the evaluation criterion becomes simply cost minimization.

All incremental capital and operating costs are included. Sunk costs in existing rights-of-way and vehicles are not included because they do not differ from one alternative to another; e.g., there are no recoverable costs (for our purposes) embedded in the existing arterial system. Many cost measures would suffice for comparison, but dollars per passenger-kilometer are given in Table 4. Because the trip is 16 km (10 miles) one way and the commuter year is assumed to have 250 days, trip cost (one way and daily round trip) and total cost per day, per commuter, and per year can be easily calculated.

The entire burden of incremental costs is assumed to

Figure 1. Short-range planning framework.

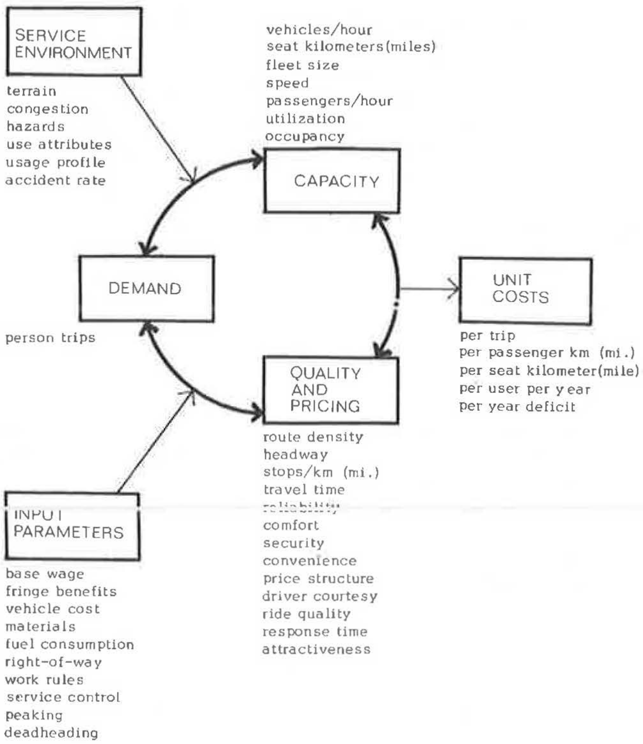

Figure 2. Generalized cost relationships.

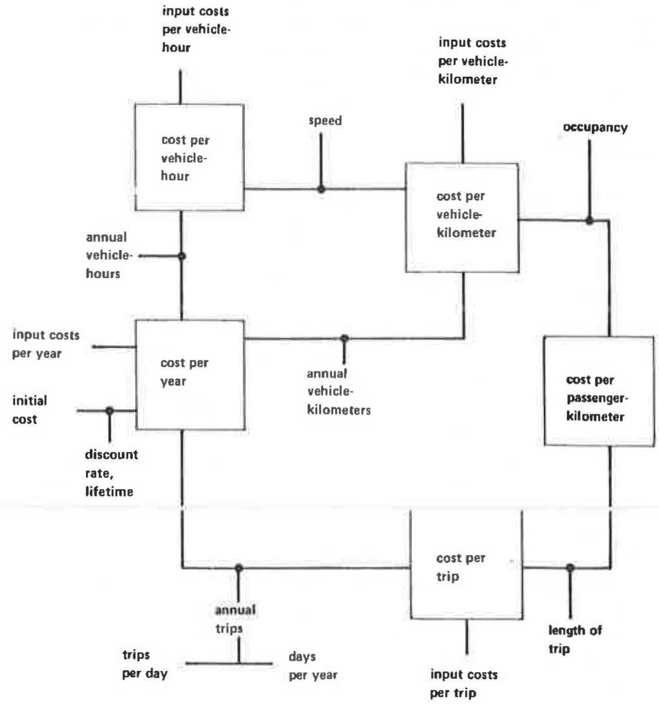

Figure 3. Northern Virginia and I-66/Metro corridor.

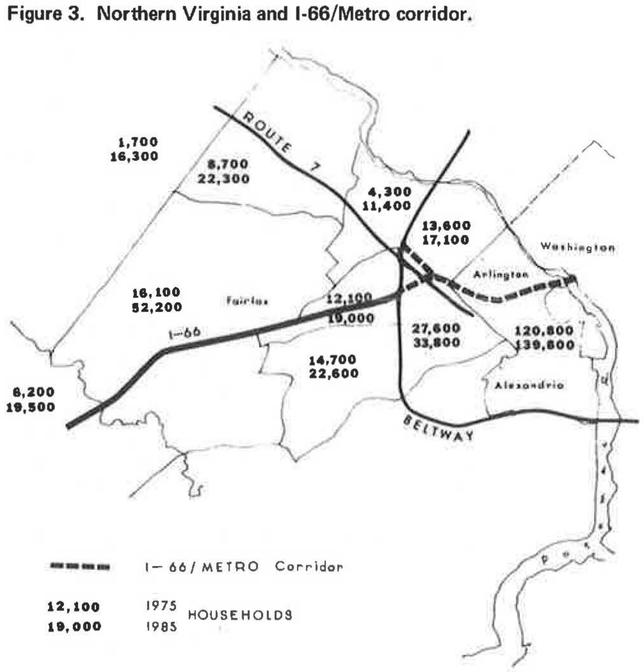

Table 1. Cost and capacity parameters for urban-suburban transportation modes.

Item	Cost (dollars)	Capacity
Six-lane freeway	2 600 000/km/year	6000 vehicles/hour
Automobile and vehicle operating	0.17/vehicle-km	4 to 6 passengers/vehicle
Bus operating	20/vehicle-hour	50 seats/bus
Bus vehicle	8000/vehicle/year	50 seats/bus
Busway	620 000/km/year	500 buses/hour
Rail rapid construction	1 000 000/km/year	300 vehicles/hour
Rail vehicle	33 000/vehicle/year	81 seats/vehicle
Rail rapid operating	80/vehicle-hour	81 seats/vehicle

Note: $1/km = $0.62/mile.

Table 2. Demand forecast.

Item	1975	1985
Households within corridor and outside Beltway	63 800	163 300
Vehicle trips by automobile	10 800	
Person trips by automobile	15 100	
Occupancy	1.4	
Person trips by transit	2500	
Person trips per household[a]	0.276	0.276
Total person trips	17 600	45 050

[a]Person trips for all purposes in the a.m. peak direction at the Beltway, as a ratio to households within zones outside the Beltway and encompassed by the I-66/Va-7 commutershed.

Table 3. Mode distribution targets (percentages) for each capacity alternative.

Alternative	Automobile	Bus	Rail	Total
Freeway	97	3		100
Rail	32	14	54	100
Busway	32	68		100
High occupancy	55	45		100

Table 4. Costs per passenger-kilometer for corridor alternatives.

Alternative	Cost (dollars)	Mode
Freeway	0.73	Automobile
Rail	0.20	Rail rapid transit
Busway	0.09	Bus on busway
High occupancy	0.08	Car pool on existing arterials
	0.06	Van pool on existing arterials
	0.04	Bus on existing arterials

Note: $1/passenger-km = $0.62/passenger-mile.

fall on peak-hour travelers. Although that is an extreme position, it is approximately accurate for the urban passenger transportation context. Even if some of the increased capacity were needed for other than peak-hour users, only a small share (10 or 20 percent) of the incremental costs might be assigned to other users.

CONCLUSIONS

Results of the first cycle of analysis led to some preliminary evaluations of the four alternatives proposed.

Alternative 1. In all respects current occupancy levels of the automobile make it an acceptable solution to the peak commuter problem. Besides the excessive cost, this alternative would substantially increase air and noise pollution, consume inordinate amounts of land, and generate enormous difficulties for the District in handling the volume of automobiles.

Alternative 2. The Metro rail alternative (supplemented by bus) is feasible from the cost-benefit standpoint, but the high mode choice requirement is probably not realizable in the short run without greater concentrations of activity around transit stations.

Alternative 3. A busway permits either integrated express service in the peak or line-haul feeder service with transfers. It has some of the disadvantages of the automobile, in that large numbers of buses would create air and noise pollution and place heavy demands on downtown Washington streets during the peak.

Alternative 4. As expected, the high-occupancy alternative is both low cost (even with an allowance for additional travel time) and low capital, in that major additional facilities would not be needed. There is, however, no democratic way to achieve it other than to charge very high user rates on automobiles and to severely restrict parking in the core area.

Although none of the alternatives appears acceptable, they suggest some combinations and reformulations that might be workable.

1. With the high-capacity, environmentally sound downtown distribution system of Metro already in place, this element ought to figure prominently in any solution to the I-66 corridor. The question is then whether to create a transfer point at Glebe Road in Arlington (where the system ends now) or to extend the line to Vienna (as planned). Other terminal stations (Tyson's Corner, west Falls Church) might also be compared.
2. Metro's downtown distribution system needs to be complemented with a system better suited to somewhat dispersed destinations, such as express bus or car or van pool systems. A joint rail-busway facility might provide sufficient benefits to justify the modest excess capacity.
3. Distribution of costs between users and general taxpayers should be tabulated, inasmuch as the user share seems to be declining on all modes.

The next cycle, obviously, will address a somewhat different set of problems and will lead to a third cycle, a fourth, and so on. One virtue of an iterative procedure is that it allows politicians, planning agencies, informed citizens, and the like to follow an issue to its resolution and provide feedback to keep the planning process on the right track. There does not seem to be another way to successfully address the complex problems we face in transportation planning.

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