An Application Of Economic Theory To Highway Finance and Planning

GORDON D. CAMPBELL,
Canadian Good Roads Association

It is necessary to adhere to an established set of principles when allocating the total road and street costs among the consumers of the service provided by these facilities. As the provision and maintenance of all segments of a nation's transportation systems, including roads and streets, require the expenditure of scarce resources, it would appear desirable to base all arguments and decisions in this area upon economic principles. Although there are many shortcomings and exceptions to classic economic theory, the basic principles of that discipline are the only ones which have evolved as a guide in how best to use scarce resources.

Essentially, the suggested economic approach is based upon the concept that the construction and maintenance of roads and streets provide a service to certain consumers — principally the motor vehicle users. Provision of this service requires the expenditure of resources. Furthermore, this service has economic value to consumers, and hence a specific quantity of service, of fixed quality, is demanded at each price established. By establishing a pricing policy for road and street service, based upon a "cost occasioned" concept, the expenditures for the roads and streets to be provided will be controlled by the demands as reflected by the revenues from the charges imposed.

Certain conclusions logically follow from an examination of the economic cost-price-demand relationships for road and street transportation service. These conclusions should have a practical bearing on the determination of highway deficiencies, highway planning and programming, methods of allocating road and street costs, determination of road and street costs, and selection and establishment of motor vehicle user imposts. Such a theoretical approach must necessarily be modified for use in practical problems.

• THE TRANSPORTATION of persons or goods upon the nation's road and street systems is a service and, as such, has economic value to individuals, communities, and the nation. Provision of this service requires the expenditure of resources to construct and maintain the various road and street facilities. These expenditures must necessarily be drawn from the limited available resources of the nation. Therefore, in providing this motor transportation service, road and street expenditures are competing for the resources of the nation with all other individual or collective expenditures such as those for food, clothing, housing, medical care, education, and defense. Each additional investment in roads and streets necessitates a reduction in expenditures for other goods and services. However, up to some limit, road and street investments will provide a greater return than alternate investment opportunities. An objective should be to establish the level of expenditures at the optimum conditions.

Road and street investment also promotes the development of the commercial motor transportation industry. This industry in turn, competes with other transportation agencies — principally the railways. In general, the allocation of freight and passenger traffic among these competing carriers is determined primarily by the rates established by each. If the most economical allocation of traffic among these carriers is desired, it is essential that these rates reflect all costs involved in providing the service. The commercial motor transportation industry causes expenditures to be made for roads and streets, both through the numbers of such vehicles operating and the size and weights of the units employed. Therefore, the road and street costs occasioned by the various commercial vehicles should be allocated to each so that these costs may influence their rates.

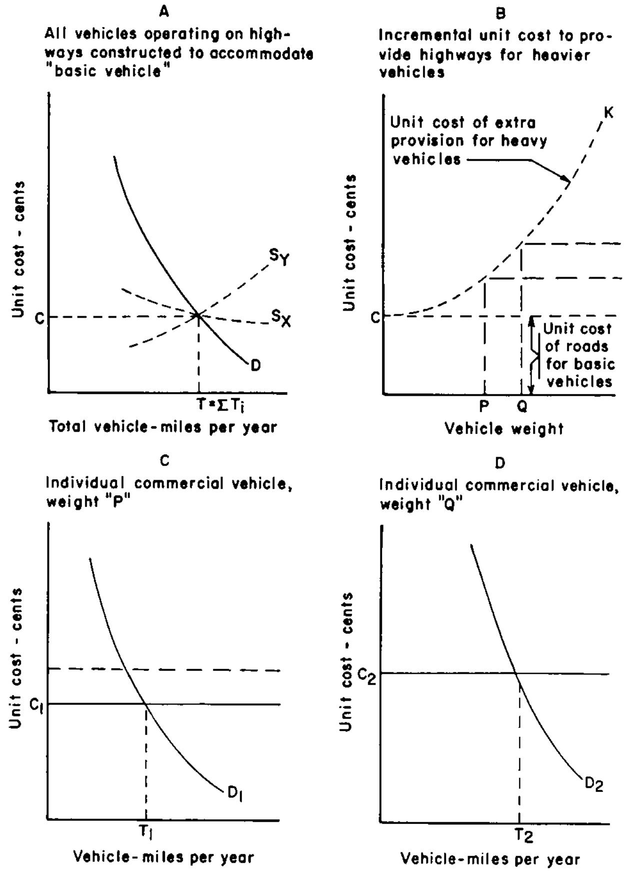
Roads and streets provide a service to all users. Under our economic system prices are, in general, used to determine the allocation of goods and services, or, in other words, the amount of any particular service to be provided. Under competitive conditions, prices reflect costs. Hence, each consumer of the road and street service (the road users) should be charged a price equal to the cost of the service provided that consumer. Confronted with this established price for the use of the road and street systems, the consumer will demand a certain amount of service. The collective demands of the consumers, as reflected by the revenues derived from the charges imposed, will determine the investment to be made in roads and streets. Thus, a criterion of charging road users according to the costs occasioned, will not only ensure tax neutrality in the commercial motor transportation industry, but will aid in establishing an economic limit on the total resources of the nation to be devoted to the provision of roads and streets.

COST-PRICE-DEMAND RELATIONSHIPS

With the above objectives in mind, the highway finance problem may be resolved into one of supply and demand. The supply of highway transportation service is determined by the capacity and condition of the road and street system which, in turn, is a function of the rate of expenditures for the maintenance and improvement of that system. The geometric design standards of a road or street are directly related to the traffic volume that is to be accommodated. The structural design of a road or street, that is, the pavement type and thickness, is related to the traffic volume (wheel load applications) and to the vehicle weights (wheel load and tire pressure) for any given subgrade soil condition. Thus, for a basic vehicle, such as a passenger car, the cost of providing a highway system of a given quality is a function of the total vehicle-miles to be accommodated in any specific period of time.

In Figure 1(A), curves S_x and S_y represent supply functions for highway systems. For either system (S_x or S_y), at a unit cost of C cents per vehicle-mile, a highway system could be provided and maintained which would accommodate a quantity of T vehicle-miles of travel in a given period (*i.e.*, one year). These vehicle-miles of travel would be distributed over the system in some existing flow pattern such that some roads are utilized to capacity while others are not. If the system were large enough and the percentages of capacity of the various segments of the system well distributed, the supply curves would be continuous functions, provided that increases in the total vehicle-miles of travel occur fairly uniformly over the existing traffic flow pattern. If the entire system, or large segments of it, reach capacity simultaneously, the supply curves would be discontinuous functions with large jumps or steps. Because the capacity of any one highway may be increased by widening the roadway or shoulders, by removing obstructions, by providing traffic signs, signals, or pavement markings, or by adding additional lanes, and because few highways in a large system reach capacity simultaneously, it is a reasonable assumption that these supply curves may be approximated by continuous functions.

Most highway systems have a great deal of excess capacity, or excess capacity may be created at a relatively small additional cost. When this condition exists, the supply curve could be a decreasing function (S_x). However, it may be that the addition of traffic to the system at any time will necessitate costly improve-



NOTES:

D - Demand curve for travel (vehicle-miles) as affected by road user imposts (unit cost per vehicle-mile) where other vehicle operating costs are constant.

S - Supply curve—i.e., the unit cost per vehicle-mile necessary to provide highways to accommodate any given total amount of travel by basic vehicles, assuming this travel is of a fixed quality (safety, comfort, convenience).

K - Supplementary supply curve for heavy vehicles—i.e., unit cost of providing road structure to accommodate vehicles of any given weight.

C - The price of providing highway system to accommodate T vehicle-miles of travel.

C_i - The price (for highway provision) of travel confronting individual vehicles. This price shall be a marginal cost of vehicle operation.

Figure 1. Static equilibrium condition for supply and demand for travel upon a highway system where all vehicle operating costs other than road user imposts are constant.

ments to certain roads (an increase to 4-lanes) and thus the unit cost per vehicle-mile will increase. In this case, the supply curve will have a positive slope (S_y). The slope and shape of a supply curve is also a function of time — the rate of investment, and the rate of increase of vehicle-miles per year to be accommodated. Exact knowledge of the shape of the supply function is not necessary for an understanding of the principles illustrated in Figure 1, but it should be realized that this function could be evaluated in practice by means of a comprehensive highway needs study in which a specific program of development was determined.

In Figure 1(A) curve D represents the demand for travel upon a highway system. Intuitively, this curve has a downward sloping trend as shown. At a high unit cost per vehicle-mile there should be less travel than at a low unit cost per vehicle-mile. This composite demand curve for the system is functionally related to all of the demand curves of individual vehicles using the system. Individual demand curves for three specific typical vehicles are shown in Figures 1(C), (D), and (E).

Assuming that all motor vehicle operating costs except road user imposts remain constant, it might be concluded that in Canada and the United States, the demand for travel by nearly all automobile owners is perfectly inelastic. This condition is illustrated by curve D_5 in Figure 1(E). Under current conditions, it seems reasonable to expect that, within realistic limits, any fluctuations in the unit cost of travel (*i.e.*, increases in the gasoline tax or registration fees) will have practically no effect upon the amount of annual travel of passenger automobiles, provided such changes are not so drastic and abrupt as to incur public animosity. It would appear that only serious external economic forces affecting individual incomes and the standard of living will have any effect upon the number of miles driven by automobile each year.

The annual travel of a commercial vehicle is determined to a large extent by the amount of transportation business available. The amount of this business is affected by the transportation rates which, under competitive conditions, are determined from the unit cost of travel. Therefore, if the unit cost per vehicle-mile is large, business may be either diverted to competitive transportation agencies or withdrawn from the market, and the amount of travel would be less than if this unit cost were small. The demand curve for an individual commercial vehicle thus has a downward slope as illustrated in Figures 1(C) and (D). It is primarily the accumulative effects of the demand curves for all commercial vehicles which causes the slope in the aggregate demand function of Figure 1(A).

The intersection of the aggregate demand curve and the supply curve of Figure 1(A) determines the price, C cents per vehicle-mile, which must be charged against the total travel T to provide an adequate highway system to accommodate the "basic vehicle." Because there is no profit or monetary return on the capital invested in highways, the price C will also represent the unit cost of providing the highway system. For any individual vehicle this price will represent a constant unit cost per vehicle-mile, because the amount of travel by one vehicle is insignificant compared with the total travel upon the highway system.

The unit cost of providing roads for the basic vehicle has been transferred to Figure 1(B). In addition to the basic unit cost, further highway expenditures are necessary to accommodate heavier vehicles. These added costs result from the provision of wider riding surfaces and from the necessity of constructing heavier pavements. For a given distribution of heavy vehicles in the traffic stream using the road system, a curve K may be determined which represents the price or unit cost of extra provision for heavy vehicles. This curve originates from the unit cost C, previously determined. Knowing the gross weight of a particular vehicle, the price or unit cost of the highway system chargeable to that vehicle may be determined. This is illustrated by Figures 1(B), (C), and (D). For each size of commercial vehicle, the point of intersection of the price and demand curves defines the annual vehicle-miles which may be economically traveled. The summation of individual vehicle-miles of travel per year (T_1, T_2, T_3, etc.) for all vehicles using the system will equal T vehicle-miles of Figure 1(A).

It should be noted that the annual travel of any individual commercial carrier (T_1 or T_2) is considerably less than the amount of travel that would have resulted had these vehicles not been assessed the unit cost of extra provision of roads occasioned by their weight. Assessing heavier vehicles in accordance with the true costs occasioned by each weight and size group places an effective and economical limit upon the amount of travel on the highway system. Furthermore, if transportation rates reflect costs, it prevents uneconomical travel from diverting commercial traffic from more efficient competitive carriers.

A pricing policy established in this manner, applied to a motor transportation industry characterized by competition and freedom of entry into the business, should bring about the most economical and efficient service possible. Furthermore, a tax structure, progressive with vehicle size and weight and reflecting the true costs occasioned by each vehicle, will define the optimum gross weight for over-the-road carriers when these charges are combined with all other vehicle operating expenses. Vehicle load limits for a highway system which are determined in this manner, are consistent with the principles of transportation economics, as all real costs involved in providing the service have been considered in the evaluation.

It should be noted that the theoretical relationships are based upon a road system of constant quality, whose over-all physical plant is being altered gradually to accommodate increasing amounts of travel. If a general improvement were to occur in the quality of service provided the motor vehicle users operating on a road system, the entire supply curve for that system would be displaced upward. This of course would necessitate an increase in all unit prices per vehicle-mile charged to the users. To a point, improvements in the quality of road service will result in reductions in vehicle operating costs. Thus, there is an economical limit to which the quality of a road system may be raised.

The theory represents static equilibrium conditions. In practice, however, motor vehicle use is a constantly expanding phenomena. To compensate for these dynamic conditions, it is continually necessary to anticipate the future demands upon the road system by means of projected increase in motor vehicle travel and anticipated changes in construction costs. This is essential if quality or service is to be maintained by providing increased or improved facilities in accordance with traffic increases. However, the pricing policy described herein is based upon the marginal cost and marginal revenue concepts. The marginal cost in this case is the unit cost of providing an addition to the road system adequate to accommodate an additional unit of travel, without altering the over-all quality of service provided by the system. Average costs over a long financial program period are not equal to marginal costs. Averaging the program costs over a considerable stage of development will result in unit road user charges which are constant over the program period and which may be excessively high during some period and low during the remaining time. Because total travel is a function of the unit cost of road user charges, the constant unit costs would provide an artificial deterrent to travel in some years and an artificial stimulus in others. Shorter financial program periods would allow the traffic demands to reflect the current costs of providing the service and, thus, the needs of the system could be more closely adjusted to the demands for travel upon it. Within the practical limits necessary for planning and constructing road improvements, it would seem desirable to reduce to a minimum the period over which a financial program is determined. In this way, average costs might approximate marginal costs. Of course, the theory would also require that road user imposts be revised in accordance with the new costs for each of these short program periods.

Throughout this discussion, the use of certain terms, which normally pervade all highway finance literature, has been avoided. Among these terms are such words as "equitable," "beneficiaries," and "benefits derived." Each of these terms has a rather nebulous meaning and invariably most individuals interpret them differently. The continued use of such terminology leads to further confusion and hinders progress toward an ultimate and satisfactory solution to the problems. The corresponding terms "economical," "consumers of the service provided by roads and streets," and "amounts of road and street service consumed" are more explicit and define more precisely the various opinions and methods offered in this area.

PLANNING AND PROGRAMMING

Road and street planning is determining what the needs of a particular system actually are and developing a plan to overcome these needs. The most critical feature of planning lies in the determination of the needs or deficiencies. Providing highways is a service which must be purchased by consumers. Therefore, highway deficiencies are actually a function of the price charged the users — or of the cost of correcting the condition of the facility. If the cost allocated to users is too high, they might prefer the existing facility rather than purchase an improved one. If this is the case, a so-called deficiency does not actually exist.

Determination of the deficiencies of a road or street facility must take into consideration the cost required to improve the condition or standards of that facility. This is a further objection to financial arrangements based on long range plans when the average unit costs of capital improvements over the program period are allocated to the users. Such arrangements do not allow consumer demands to influence the quantity and quality of the road and street facilities to be provided.

Related to the problem of highway needs is the method used to determine construction priorities for programming purposes. Today, the most commonly used priority scheme is the "Sufficiency Rating Method" (*3*). A weakness in this method is the failure to consider the cost element. An economizing problem confronts the determination of priorities; therefore, the returns from each investment must be considered. A fiscal rather than physical device is needed to determine priorities.

To evaluate deficiencies and determine priorities, an analysis technique, which in general conforms with the economic objectives, is available. This is the so-called "benefit-cost ratio" (*4*). As used in such analyses, "benefits" may be considered as both a measure of consumer demand and an evaluation of returns from road investment. If evaluated correctly, a ratio in excess of 1 would indicate a deficiency, while the higher this numerical ratio, the greater is the priority for improvement. Although the present technique used in determining the benefit-cost ratio is inadequate, this type of analysis is worthy of further investigation, research, and development.

ROAD AND STREET COSTS

In the suggested theory of finance, it is essential that all of the costs occasioned by each consumer of road and street service be allocated to that consumer in proportion to the rate of consumption. The first step in such a procedure is to determine what actually constitutes the appropriate costs. Initially, the component expenditures must be itemized, for example: capital investments; maintenance, operation, and administration expenses; interest on bonded indebtedness; and traffic control and enforcement costs. A further item of importance in urban areas is the cost of parking. Full parking costs, when included with other charges for the use of streets, will permit motorists to decide on the basis of total economic costs, whether they wish to enter the more congested areas of cities by automobile or mass transit.

When confronted with the total costs of travel and parking, there might be less tendency for individual vehicles to approach or enter the central business district of cities. In this way, parking costs will aid in establishing an economical limit to the demands for travel upon a city's arterial street system. Without allocating the total parking costs to motor vehicle users, it would be impossible to achieve an economical balance between street costs and travel demands in urban areas.

On the basis of the outlays necessary for the provision of a road or street system, there are two possible approaches for determining the annual revenue requirements. These two methods are generally entitled the "annual cost" and "annual expenditure" theories. The annual cost approach includes an annual amortization charge to spread the construction outlays over the period of years during which the improvement will be serviceable. In this way, the consumers who actually use a facility during its life will each be charged for that capital improvement in proportion to the extent of such use. It should be recognized that, neglecting the interest element of the annual cost approach, the costs calculated by this method will approximate actual annual expenditures if a program is used in which the capital investment is nearly equal in each year. However, the theory indicates that forcing the equalization of capital expenditures over a prolonged period is not desirable. Thus, as unit costs, total travel and time may not be related linearly, the annual expenditure method would not yield the same results as the annual cost method. The annual cost approach would seem preferable as it generally conforms with the theory advocated.

Annual cost customarily contains an interest charge on the unamortized amount of the capital investment. This interest charge is a justifiable item, representing a true opportunity cost, when used in a comparative economic analysis. However, in determining costs for allocation to road and street users, the interest charge is fictitious and should not be included.

METHOD OF COST ALLOCATION

The theory under consideration attempts to charge each road user a unit price per vehicle-mile equal to the unit road and street cost occasioned by that vehicle. If the motor vehicle did not exist today, property owners or the general public would undoubtedly demand that some "basic road" be provided to render adequate access to the various properties of a region. With the motor vehicle, a much higher type of facility is demanded. If these two demands for roads were separable, it would be economically sound to allocate the total road costs in accordance with the ratio so established. That not being the case, it is necessary to assume that the demands of the property owners would be independent of those of the motor vehicle users. Therefore, the "basic road" would be demanded by the property owners, and the costs of this unit would be attributable to these consumers. Such an assumption does not appear to be unreasonable.

The road and street cost responsibility of the property owners and general public could thus be determined in accordance with the "added expenditure theory" or the "basic access highway responsibility method" (*2*, *5*). Another approach would be to define the basic road as a road or street whose annual cost per mile was equal to the average annual cost per mile of the adjacent local road or local street system. The local systems should represent the property owners and general public's demand for a facility not designed for through traffic. All costs of any road or street facility in excess of the costs of a basic road would be assignable to the motor vehicle user group. A cost allocation method of this nature would approximate the requirements of the economic theory.

The theory of differential costs (the incremental theory) should be used to allocate the total tax responsibility among the individual units comprising the motor vehicle user group (*5*). This theory attempts to evaluate curve K of Figure 1(B), to distribute the basic costs to all vehicles on a mileage basis, and hence to determine the costs assignable to any particular vehicle. In other words, the economic theory may be applied in practice by means of the incremental method, if the appropriate point on the supply curve for the road system is determined.

MOTOR VEHICLE USER IMPOSTS

From this theory, it may be deduced that the motor vehicle user charges should be collected at the time the road or street service is consumed in order that the user might base his travel decision on the relevant economic costs of this and alternate investment opportunities. It is impossible and impractical to provide a toll gate at every road and street intersection. However, motor fuel taxes and mileage taxes do satisfy the specifications, provided they can be combined or adjusted to yield a progression with size and weight which is comparable to that determined in the cost allocation analysis. Imposts which vary with travel and which are payable at the time of the travel would appear to be more satisfactory than large fixed annual license fees.

As motor vehicle user imposts should represent a toll payment for the use of roads or streets, only those costs associated with such use should be charged. Thus, vehicles operating in more than one province or state should pay for the use of the roads and streets in each jurisdiction at essentially the same rate per mile as an intraprovincial or intrastate vehicle of the same size. For a satisfactory implementation of the theory, it is essential to overcome the current difficulties of the reciprocity problem.

CONCLUSIONS

If the objective of a national, state, or provincial transportation policy is to provide the most economical over-all transportation system for that jurisdiction, the highway finance problem should be resolved in light of accepted economic theory. The basic cost-price-demand relationships for road and street use should constitute the fundamental criterion for the solution to the planning and cost allocation problem. An examination of these relationships will reveal the importance of the marginal cost and marginal revenue concepts. Of course, market conditions do not exist in highway supply, and it is impossible to adhere strictly to the dictates of these principles. However, the basic concepts should be borne in mind in highway planning, programming, and financing. Within the practical limitations of timing road and street development, it appears desirable to adhere to these concepts in order to promote an economical and logical evolution in highway motor transportation and in all transportation.

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