CONSUMER SURPLUS DOES NOT APPLY TO HIGHWAY TRANSPORTATION ECONOMY

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The consumer surplus concept is based on the price-demand relationship that states that, if the consumer price of a commodity is lowered or increased, then the number of units sold will be reduced when price increases and increased when price decreases, if all other factors remain constant. Consumer surplus is the difference between the total price paid by all customers and the total amount those customers would have been willing to pay. This paper concludes that the consumer surplus concept has no justifiable application in the analysis of the economy of highway transportation investment alternatives. This paper is related to only those consequences of highway improvement that are market priced: highway facility costs, motor vehicle running costs, traffic accident costs, and travel time. This paper is not concerned with the decision-making process except to furnish the decision maker with a thorough and reliable analysis of the transportation costs for each alternative considered. Traffic volume composition is discussed, and specific attention is paid to generated, or induced, trips. For the time span of years chosen for the analysis of transportation economy, it is concluded that generated traffic (trips that come into being solely because of the reduction of trip costs) cannot be estimated for the analysis period reliably. Furthermore, estimating consumer surplus is not necessary because total transportation cost of each alternative considered is the only relevant factor. The shift of the price demand as highway design or traffic control changes is discussed. This shift cannot be determined either in scope or direction, and, therefore, the net change in consumer surplus cannot be determined.

•IN THE past 10 to 15 years, the economist's concept of consumer surplus has been increasingly applied to highway transportation, usually in the cost-benefit analyses for evaluating proposed capital investments. In an analysis of the transportation economy of proposed highway capital investments, the economist's consumer surplus concept should not be applied.

Consumer surplus, in certain situations, may be useful in evaluating some aspects of transportation. This paper, however, is restricted to the cost-benefit analysis of proposed highway investment alternatives for transportation economy (resource conservation) that produces answers in the form of equivalent uniform annual cost, present worth of costs, benefit-cost ratio, or rate of return when such answers are used as guides to determine whether to invest and what engineering design to use.

I wrote this paper because I felt that highway engineers do not understand the concept of consumer surplus and that economists do not understand the differences between the relationship of highway users and highway transportation and the relationship of consumers and consumer commodities on the open market.

Consumer surplus is based on the idea that customers buy more of a produce solely because of a lowering of its market price. No other factor is involved. In highway use, drivers select their routing and take trips with little or no regard to the cost for a specific trip. They may choose to use a new facility or an improved old one for many reasons. The cost in dollars or travel time may be included or not included in the decision making. Certainly, cost, or price, is not the sole cause of an increase in traffic that may result from a highway investment.

In this paper, the discussion of the application of consumer surplus to economic analysis is limited to determining the transportation economy differences of 2 ways of investing capital or changing the monetary costs of transportation by changing highway design or traffic operations. Thus the costs involved must be priced in dollars. All nonmarket factors, although they are important to decision making, are excluded. A change in the cost of transportation—a decrease or increase in price, P—must be in dollars, and the price must be recognizable by the driver. Under the concept of consumer surplus, this situation exists because usage (or sales) is increased when prices are lowered, if all other factors remain unchanged.

Economic analysis of the economy of improvements to highways is for 2 purposes. First, the improvement is to be evaluated economically. In other words, Will it pay off in reduction of capital and operating costs? Second, engineering design must be evaluated. In other words, What design produces the desired quality of travel service at the lowest cost?

Engineering design in no way can be related to consumer surplus because the alternative designs must be for the total traffic expected and the cost to use each facility regardless of the source of the traffic.

Quantity of use (or of sales in a commercial application), Q, is measured in number of vehicle trips. The commodity purchased at P then is Q trips. In some analyses, distance per trip may increase or decrease with or without a change in the number of trips.

DEFINITION OF BENEFIT

In the literature dealing with analysis of public works proposals for investment of public money, the word "benefit" is used widely but seldom defined. Perhaps some of the misunderstandings in the literature arise because of this. Benefit often is confused with savings, cost reductions, and personal preferences of the driver.

Some of the meanings of the word benefit include:

1. A monetary cost reduction based on market price,
2. Increased personal satisfaction (not priceable),
3. Enhancement of one's personal preferences (not priceable),
4. Improvement in social, economic, and environmental conditions in the affected areas (usually not priceable), and
5. Difference between actual price and a higher price one would be willing to pay.

The discussions in this paper on consumer surplus are related to priceable cost changes (resource conservation) that can be used as a measure of the profitability of the proposal as a transportation facility. Item 1 from the listing is the only item that will be considered.

The other items are highly important and must be considered in the total decision-making process. But unless a factor can be market priced in the same way that highway structure and motor vehicle running costs are priced, then it cannot be merged with highway costs and motor vehicle running costs.

This restriction results in the exclusion of any consumer surplus that is strictly a value concept such as that of item 5. Of course, consumer surplus that results directly from a price or cost reduction is included.

Benefits also may include values that are not comparable in the same dollars as cost or market price dollars. But a value dollar as a willingness-to-pay value is not equivalent in economic value (economic feasibility or engineering design analysis) to a dollar of cost reduction or resource conservation. This statement is true for value-of-transportation time when such a time value is expressed in terms of "willingness to pay." Economy of transportation should be based on resource consumption and not on value or willingness to pay.

CONSUMER SURPLUS

The consumer surplus concept is shown in Figure 1. It is a simple and correct concept as devised, but its application to highway transportation is not so simply or so directly related as is assumed by many engineers and economists. Its use in highway economic analysis may be challenged justly.

Figure 1 is explained according to the consumer surplus concept derived 130 years ago. The price-demand curve D_0 represents the relationship of the price per unit of commodity to the number of units of that commodity that would be purchased by all customers at that price at that time and place. Thus, at P_0, Q_0 units would be purchased. If the price were to be reduced to P_1, Q_1 units would be purchased.

The consumer surplus at P_0 is the area A_0 within the horizontal price line P_0, the price-demand curve D_0, and the vertical price axis. This consumer surplus is a value concept, not a cost or price concept. This concept comes from the fact that some purchasers of the commodity are willing to pay more than P_0, but, because market price is only P_0, these customers gain a value surplus equal to the difference in price they would be willing to pay and the lower price P_0 that they actually pay on the market. This difference is their consumer surplus. At Q_0, some customers buy because the price is slightly below the maximum price they are willing to pay. And some potential customers do not buy because the market price of P_0 is slightly above the maximum price that they are willing to pay. At this marginal price, then, a slight change in market price—either downward or upward—would shift the number of Q_0 units higher or lower. The price-demand curve is a representation of this change in number of units purchased with a change in unit price. Note that at P_0 the consumer surplus that exists is the total area A_0 above the P_0 price line and that this surplus is a value concept. That is, consumer surplus is the amount of total purchase price the consumer is willing to pay less the amount actually paid at market price P_0.

If the market price is lowered to P_1, the number of units purchased becomes Q_1, and the consumer surplus is increased by the rectangular area A_1 and the triangular area A_2. But note that A_1 is an actual reduction in dollar cost to the customers of the Q_0 units, provided that they purchase the Q_0 number of commodities at the new price of P_1. The triangular area of A_2, however, is a value concept for those who purchase the increase in number of commodities of Q_1 - Q_0. The consumer surplus of the triangle is attributed to the new customers only. Of course, the total change to the consumer surplus is the sum of the rectangle A_1 and the triangle A_2. But note that A_1 is a cost reduction and that A_2 is an increase in a value concept. The new customers collectively have gained the satisfaction of being able to buy the commodity at a price below the maximum that they are willing to pay, but they have not experienced a reduction in expenditures required to sustain the same level of living. In fact, they spend money for a new commodity (or more for an old commodity), and this money must come from a change in their spending habits. They have to give up one commodity to obtain another.

Strong emphasis must be placed on the basic premise of the economic concept of consumer surplus. First, only the price of the commodity is changed. The commodity must remain at the same quality and meet the same standards. It cannot be "new and improved." Second, the time period considered must be so short that customers and potential customers will not have changed their relative values and attitudes toward the commodity. If such changes occur, then the D_0 demand curve no longer applies. As proof, consider improving the quality of the commodity shown in Figure 1 and holding the price at the same level. When an improved commodity is sold at the same price, more units would be sold. But, with P_0 unchanged, the point for increased sales would fall to the right of Q_0. This means that a new price demand is established. Furthermore, by both improving the product and increasing the price, one can sell more items. In effect, if the quality, serviceability, attractiveness, or utility of the commodity is changed, the result is essentially the establishing of a different commodity and the development of a new price-demand relationship.

The price change must be recognized by the customer (or highway user). If the price change is not recognized, the purchaser (or traveler) would not be buying because of a price change. The fundamental situation shown in Figure 1 is that the increase

in numbers of units purchased results from the lowering of the price. Unless this change in price is recognized by the purchaser, there would be no known factor leading to a change in Q.

APPLICATION TO HIGHWAYS

Figure 2 shows how the consumer surplus concept is related to highway improvements when cost-benefit analyses are concerned. It is generally accepted that capital improvements to highways result in lower travel costs and decreased travel time or both to the users of highways when the new and improved highway is compared to the situation before improvement. Such a change in user costs is represented by the lowering of the cost per trip from P_0 to P_1 as shown in Figure 2.

Improved highway facilities, however, usually change the quality of the ride and trip, and therefore may attract new trip makers, more use by old trip makers, or a decrease in the number of trips. Changes in the quality of highway service (comfort, convenience, scenery, view from the road, change of roadside culture, new routing) generally are not priceable on the market. Therefore, they are not reflected in the price reduction from P_0 to P_1. But these qualities, the personal preferences of the users, are reflected in the increase of trips from Q_0 to Q_1. The result is that a new price-demand curve is generated as shown by the D_1 demand curve, which, in effect, applies to a different commodity. Here, there is a departure from the original concept of consumer surplus because changes other than price are introduced.

In Figure 2, the area A_1 still holds as the measure of the reduction in costs to the Q_0 users as effected by the highway improvement. The area A_2 also would be retained as a value measure of the increase in the consumer surplus gained. A new area, however, now must be considered. Because of a shift to the right of the price-demand curve, the shaded area A_3 between the 2 demand curves is added to consumer surplus in the sense of value. The triangle ACD no longer measures the total increase in the value component of the increase in consumer surplus. The added value now is ACD plus the shaded area A_3.

The gain in consumer surplus existing outside the cost reduction rectangle A_1 cannot be measured practically because no way exists to establish the 2 demand curves. Perhaps one can state correctly that point A is properly located on price-demand curve D_0 and that point B is established on demand curve D_1. One point, however, does not establish a curve.

Highway users do not fit consistently into the general concept of consumer surplus. For example, a decrease in price will not necessarily result in additional trips, nor will an increase in price necessarily result in fewer trips. Over the period used in the economic analysis, the personal value of trips changed as shown by the fact that, as traffic volume increased, overall road user costs increased. This also contradicts the consumer surplus concept that states that as unit costs decrease quantity of sales or trips increase.

The price-demand curve for the highway, road, and street user is forever changing with time. During the normal 24-hr day, the price-demand curve changes from hour to hour. During the hours of light traffic volume road user cost is the lowest; at peak hours the cost is highest and the number of trips is highest. Here the unit price is higher, but, contrary to the consumer surplus concept, the number of trips also increases.

In highways, the price of a road user trip is not deliberately lowered or raised by managerial decision. The price of the trip is changed by changing the highway design or traffic-flow conditions. In this type of change, a new consumer surplus situation occurs where any change in the use of a changed facility may result from a cost of trip change or a change in trip character or both. A change in trip quality that results in a change in user attitude toward the trip may be regarded as a change from one commodity product to another commodity, and, therefore, a change from one unknown price-demand curve to another unknown price-demand curve.

Figure 1. Price-demand curve for purchasing a specific commodity.

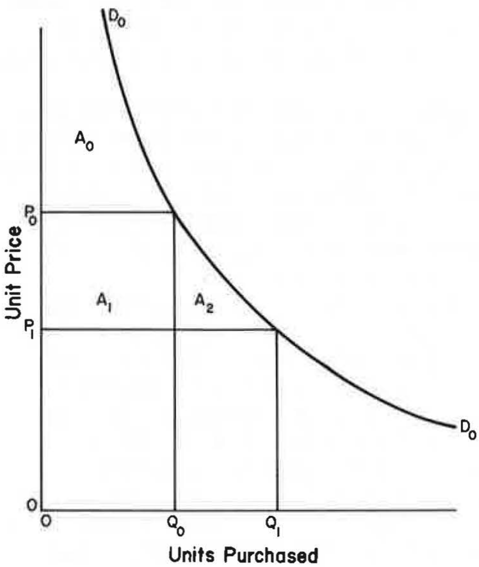

Figure 2. Price-demand curves for highway trips before and after highway improvements.

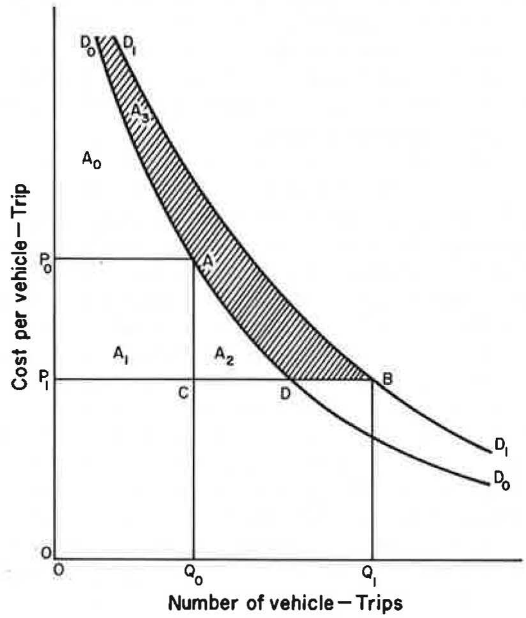

Table 1. Possible effects of highway improvements on price and number of trips.

	Changes in P and Q[a]					
	P minus, Q minus	P minus, Q same	P minus, Q plus	P plus, Q minus	P plus, Q same	P plus, Q plus
Highway Improvement or Situation	A[b]	B[b]	C[b]	G[b]	H[b]	I[b]
New highway at a new location	0-X	0-0	0-X	0-0	0-0	0-X
Reconstruction of existing highway	0-X	0-0	X-X	0-0	0-0	0-X
Widened lanes and shoulders	0-X	X-0	X-X	0-0	0-0	0-0
Added lanes	0-X	X-0	X-0	0-0	0-0	0-X
Widened bridges	0-X	X-0	X-X	0-0	0-0	0-X
Lengthened sight distance	0-X	X-0	X-X	0-0	0-0	0-X
Increased radius of horizontal curves	0-X	X-0	X-X	0-0	0-0	0-X
Construction of grade separations	0-X	X-0	X-0	0-0	0-X	0-X
Railway crossing protection systems	X-X	X-0	X-X	X-X	0-0	0-X
Closing of intersections and access to abutting property	X-0	0-0	0-0	0-0	0-0	0-X
Spot safety improvements	0-X	X-0	X-0	0-0	0-0	0-0
Ramp metering, effect on freeway traffic	X-0	X-0	X-0	0-0	0-X	0-X
Ramp metering, effect on ramp	0-0	0-0	0-0	X-0	X-X	X-X
Directional traffic flow	0-X	X-0	X-0	0-0	0-0	0-X
Intersection channelization	X-X	X-0	X-0	X-0	X-0	X-X
Traffic signs and signals	X-X	X-0	X-0	X-0	X-0	X-X
Lighting	0-0	X-0	X-0	0-0	0-0	0-X
Improved roadway surface or shoulder or both	0-0	X-0	X-0	0-0	0-0	0-X
Roadside beautification, generated traffic	0-0	0-0	0-0	0-0	0-0	X-X
Growth in traffic volume over years	0-0	0-0	0-0	0-0	0-0	X-X

[a] In the entries, the first 0 or X refers to the highway segment on which the improvement is made. The second 0 or X refers to other segments of routes within the network affected by the improvement. The 0 indicates no effects are probable, and the X indicates that some effects are probable. The changes shown at the column headings refer to the combination of change in P and Q.

[b] Consequence class taken from Figure 3.

HIGHWAY IMPROVEMENTS AND PRICE-DEMAND CURVES

For highways, a change in number of trips brought on by a highway improvement is difficult to establish. An entire geographic area traffic pattern may be rearranged by a shift of travel routings. Traffic diverts from one route to others and from one mode to others; new trips are generated; certain trips are discontinued; and relocation of businesses and people caused by highway improvements affects the number of trips, their length, and their purposes.

In analyzing the transportation economy of any proposal to alter existing highway design or traffic control at a spot location, route, or system of routes, one must consider all consequences to road user costs, and, therefore, all traffic behavior whenever these consequences may affect the cost of transportation. An often-expected consequence is that traffic flow will increase after the improvement on the route. This flow increase, to a large extent, will be composed of users attracted from other routes to the newly improved route. And this decreases the number of users of those routes.

For spot improvements to improve traffic flow or decrease traffic accidents, the number of trips may not change, and the users may not be conscious that their costs and travel time are affected. In many improvements to local roads and streets that mainly serve as land access, the number of road user trips remains constant after the road improvement because there is no alternative routing or through traffic. In these cases, despite the lowering of road user costs, the number of trips does not change (except possibly over time and then not because of the road improvement).

The changes in the price-demand curve for highways include 6 of 9 possible combinations of plus and minus changes and no change in both P and Q. These changes depend on the specific character of highway design, the functional character of traffic, geographical location, and whether the change is at a local spot on the highway, a highway route of a mile (1.6 km) or more in length, or a highway system. In the analysis of the economy of transportation, some of these factors are illustrated by the data given in Table 1, which relate the type of improvement to changes in P and Q on the route segment improved and to other network route segments. The amount and probability of changes in P and Q are not indicated.

Figure 3 shows 6 specific classes of consequences, A, B, C, G, H, and I, based on change in price per trip (cost to road user) and number of trips before and after improvements. There are 9 possible combinations of P and Q. The 3 classes that do not change P are omitted in Table 1 and Figure 3 because, if Q is changed, then P must also change, and an improvement that changes neither P nor Q is of no interest here. The price of a trip may be reduced or may be increased. The number of trips may be reduced, remain the same, or be increased.

It is important to keep in mind that the price-demand curves shown in Figure 3 are hypothetical. As stated earlier, the shape and location of a price-demand curve for free public highways under a wide range of uses have not been determined. About all that has been done or can be done is to determine one point for the existing situation and another point for an estimated future condition. Because of a change in the quality of the trip, these 2 points are not for the same set of conditions. The result is 2 points each for a different situation (commodity).

Whether the number of trips over a section of highway increases, stays the same, or decreases as a result of changes in geometric design and traffic control depends on how highway design changes or traffic changes affect the trip distance, vehicle running cost, travel time, accident potential, driver preferences, and alternate routings. The decision of the driver to change to an alternate route depends on 3 main factors:

1. Awareness of highway change;
2. Consciousness of effects of highway and traffic change on running cost, accidents, travel time, and preferences; and
3. Relative costs and satisfactions of alternate routes.

Figure 3. Price-demand curves for before and after values of price and number of trips.

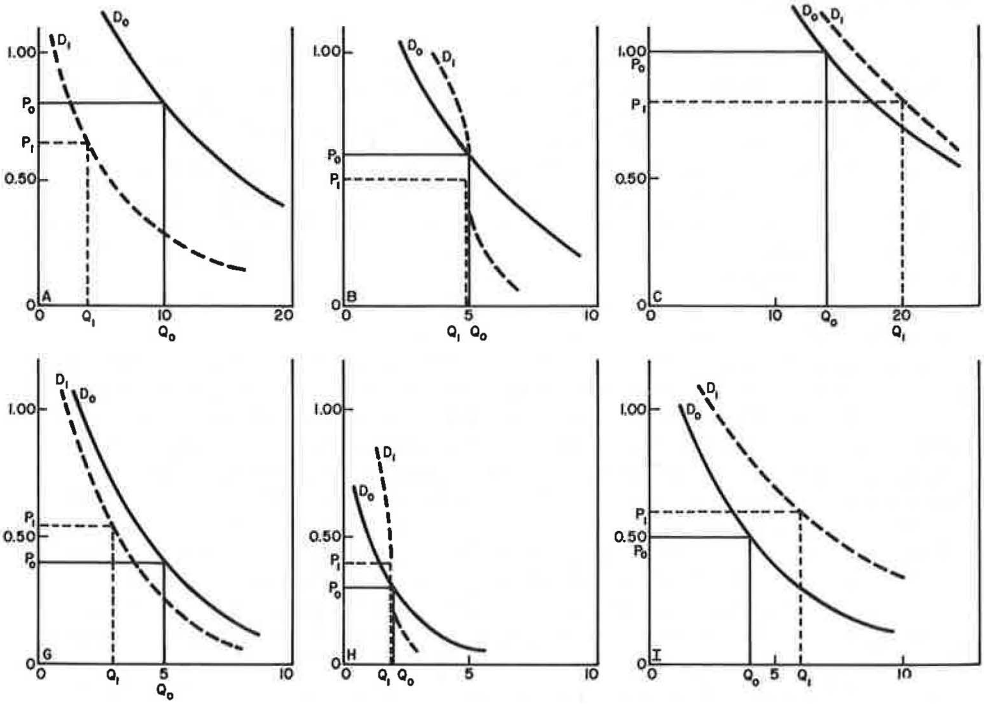

Table 2. Unit costs, number of trips, and user costs on highway segments before and after improvements.

		Before Improvement			After Improvement			
Consequence	Changes in P and Q	Unit Cost Per Trip (dollars)	Number of Trips	Total User Cost (dollars)	Unit Cost Per Trip (dollars)	Number of Trips	Total User Cost (dollars)	Change in Consumer Surplus (dollars)
A	Decrease in both P and Q	0.80	10,000	8.00	0.65	4,000	2.60	1.05
B	Decrease in P and no change in Q	0.60	5,000	3.00	0.50	5,000	2.50	0.50
C	Decrease in P and increase in Q, improved segment	1.00	14,000	14.00	0.80	20,000	16.00	3.40
G	Increase in P and decrease in Q	0.40	5,000	2.00	0.55	3,000	1.65	-0.60
H	Increase in P and no change in Q	0.30	2,000	0.60	0.40	2,000	0.80	-0.20
I	Increase in both P and Q	0.50	4,000	2.00	0.60	6,000	3.60	-0.50
Totals			40,000	29.60		40,000	27.15	3.65
Net change							2.45	+3.65

WHY NEW PRICE-DEMAND CURVES DEVELOP FROM CHANGED HIGHWAY DESIGNS

On any particular route or segment of a route at any given time, traffic volume results from the exercise of driver preferences. Each segment has its own characteristics that are considered by the drivers of vehicles. Each segment competes with other route segments for the driver's choice. These characteristics of the route together with the driver's attitudes toward them establish the price-demand curve for each particular route segment. For these reasons, new price-demand curves are established for routes or segments of routes that undergo design or traffic control changes. This change in price-demand curves also applies to other route segments in the total network that are affected by the improvement.

The consumer surplus concept as applied to use of highways can be related to the purchase of standard commodities on the market and their competitive alternatives. Butter and margarine are competitive foods. Customers have their own price-demand curves for butter and margarine. Price difference and customers' attitudes toward the products are involved. There are users who do not buy margarine regardless of price difference. Other users will not buy butter as long as margarine is lower in price. There are perhaps 20 different varieties of bread available to a customer. These varieties do not have the same price-demand curve to a specific customer because they are not the same product. As with butter and margarine, the many varieties of bread serve essentially the same function as a human food, but there are differences in the quality of their service (nutrition, taste, texture, etc.) and personal preferences. Thus a change in price or quality or both will alter the number of items sold. Changing just the quality of a specific brand of butter or specific brand of bread will alter the quantity of sales; it also will alter the shape and location of price-demand curves.

Highways are the same with respect to their choice of use by drivers. The use of a specific highway route or segment thereof is a result of the characteristics of that highway, the characteristics of traffic on that highway, and the personal preferences of the vehicle drivers. A choice of routes is made with respect to these characteristics.

The characteristics of a route and traffic on that route at any particular time include many factors. Some of the highway design factors include plus and minus grades, horizontal curvature (both number and extent), pavement and lane width, shoulder width, bridge width, pavement smoothness, number of roadside access points, number of intersections, median, access control, and distance. Traffic factors include items such as number and type of traffic control devices, handling of left-hand turns, whether the route is 1- or 2-way, whether it is lighted, traffic mix (number of cars, buses, and trucks), traffic volume, relative speeds and speed changes, relative safety, potential traffic delays, probable driving time, and pedestrian interference. Roadside factors include types and density of roadside structures (residential, business, or industrial); openness of view, which involves height of buildings and width of right-of-way; probability of crime; characteristics of people in the neighborhood and in vehicles; and scenic and historical values.

Considering these 3 groups of factors in total, one finds that evidence exists to expect essential differences in the price-demand curves for specific segments of highway routes and that the people using each segment made their selection according to their personal preferences. When an improvement is made to a specific highway route segment, there is a shift in the total traffic in the affected area, according to these personal preferences. Two significant results come about: (a) traffic mix changes and (b) volume of traffic changes. These 2 changes are found on the route segment improved, other network segments, and connecting and access ways between these route segments. Furthermore, new trips may be generated and old trips may be discontinued on any of these segments or connecting ways.

On existing routes of known traffic volume and mix of vehicles, total user costs are calculated from unit prices of vehicle running costs, traffic accidents, and travel time. These unit costs in no way relate to the drivers' valuations of other factors on which they may have based their preferences for the route segment under study. These unit costs are costs per vehicle mile (kilometer), cost per traffic accident, and hourly

dollar values for travel time. However, average daily traffic (ADT) volume is a result of the other factors named in the list of design, traffic, and roadside factors. Therefore, in the analysis of transportation economy, user unit costs are determined for a particular route segment and applied to forecasted ADT segment by segment. The forecaster is assumed to have taken into account all factors that affect ADT after completion of the improvement to the route segment under study and other network segments affected. It follows then that in the analysis for economy of transportation the user costs for both the existing highway and the highway after improvement are calculated by applying to the ADT user unit costs that do not include any allowance or pricing for nonuser factors or factors other than those determined on a unit cost basis for similar highway designs, traffic operations, traffic accidents, and travel time.

Factors other than market priceable road user costs affect both existing and future ADT on all affected route segments. This is why highway improvement to an existing segment results in a new price-demand curve. Also, other route segments that are affected most likely develop new price-demand curves because of the competitive nature of route choices and varying traffic volume and traffic mix as ADT increases or decreases. This shifting of the price-demand curve is shown in Figure 3.

The conclusion of this paper directly contradicts the conclusion of some economists who state that there is no shift in the shape or location of the price-demand curve. Instead, there is an actual lowering of the price in the mind of the user to a level just below the P_1 computed price. In this concept the added consumer surplus may or may not approximate the added area between the two price-demand curves in Figure 2. But, when Figure 3 is examined, the concept is seen to have little validity. Furthermore, the calculation of P_1 is prepared from prior calculations of running cost, accident cost, and travel time, and totally independent of what goes on in the minds of the vehicle drivers.

EXAMPLE

To illustrate the changes in that portion of the total highway transportation cost attributed to motor vehicle use and the changes in consumer surplus that could result from any given highway improvement, a hypothetical example is given in Table 2. The example assumes that (a) the improvement is the reconstruction of a given route segment in an urban area on the same general alignment so that a known existing traffic is contrasted to the situation of new construction on a totally new route; (b) within the highway network affected no new trips are generated, and all old trips are continued; (c) vehicle miles (kilometers) of travel may have changed, but both plus and minus changes are included in the road user cost per trip as given in the assumed data; and (d) for simplification and to hold calculations to a low number, only 6 route segments affected are illustrated, including the segment improved. Figure 3 shows the curves and lines to the scale of Table 2. It should be noted that $3.65 is not the total change in consumer surplus but is only that area between the P_0 and P_1 price lines and the 2 price-demand curves between these 2 price levels. The change in the consumer surplus area above the P_0 price level (Figure 3) cannot be calculated because the location of the 2 price-demand curves above the 2 price-level lines is not known.

This calculation does not indicate that calculation by the 2 procedures will always give an increase in consumer surplus greater than reduction in user costs. Answers in each case will depend on the relative change in the user unit costs and the change in traffic volume for each of the many route segments affected by the highway improvement. This calculation does illustrate, however, that the location and shape of the before and after price-demand curves must change because of the location of the pair of plotted points, particularly when Q decreases.

Table 2 does not give the before and after total consumer surplus. These values cannot be calculated because complete price-demand curves above the horizontal price lines are not known. Therefore, only that change in consumer surplus that is restricted to the area between the P_0 and P_1 price levels is calculated. These restrictions are more easily identified in Figure 3. It must be kept in mind that the price-demand

curves in Figure 3 are assumed. No information exists to determine their shape and direction.

These calculations raise 3 significant problems for calculating change in consumer surplus. First, in segment C, should the improved highway segment have been totally on new location, there would be no known P_0 level or Q_0 for want of any traffic on that segment. In this case, the full price-demand curve D_1 would have to be above the price level P_1 so that the gain in consumer surplus could be calculated. Second, in segment A, if the new price P_1 were extremely high, Q_1 would approach 0 at which point the area of consumer surplus above P_0 would need to be known to calculate decrease in consumer surplus. Third, if the highway improvement resulted in the abandonment of a substantial length of route segment, how could this decrease in consumer surplus be calculated?

One of the principles of economic analysis is that all consequences of a proposal to make a change must be evaluated for whomever these consequences may affect. Therefore, one must calculate the total change in consumer surplus and total change in user transportation costs for the network of routes affected by the proposal under study.

Whatever procedure is adopted should be such that it provides for calculating all changes within the concepts used (road user costs or all changes in consumer surplus) regardless of their magnitudes or their probability of occurrence. The straightforward calculation of the change in user costs for the network affected is possible in all cases, but the change in consumer surplus cannot be calculated for all cases.

REQUIREMENTS OF ANALYSIS PROCEDURE

Highway departments construct, reconstruct, modify, add to, and take away from existing facilities in a number of ways. The analysis procedure must be capable of isolating the difference in transportation cost (and number of trips) or consumer surplus that results from proposed changes in highway design and traffic controls. Consequences of these changes in design and traffic must be determined for the initial, or immediate, time date and for some future period of 5, 10, 15, or 20 years. The procedure of analysis for economy must be applicable to a local spot improvement in the geometry of the highway and traffic flow as well as to rural and urban freeways that affect traffic over a wide area of highway and street networks. For each section of highway, road, or street that may be affected by a specific alteration in highway design or traffic control, estimating the traffic volume and its composition before and after the improvement is fairly reliable. Should, however, the necessity for separating generated (induced) traffic be present, the difficulties and uncertainties would be greatly increased, particularly on a route segment basis.

The situation is further handicapped when the analyst wishes to calculate the change in consumer surplus compared to the change in road user transportation costs. The entire street and highway systems affected by the proposed improvement would need to be identified in terms of the 6 possibilities shown in Figure 3.

Over time, let us say a 20-year period, the situation becomes more complex and defies any reliable analysis of the net change in consumer surplus. People's values of most aspects of living change with time, and this includes highway price-demand curves. Thus travel patterns, cost concepts, and land use changes are altered not because of the specific highway improvement in the past but because of changing technology, customer desires, public works of all kinds, geographic shifts of business and industry, changing government policies, economic factors, and social forces. Also population increases; use of vehicles may increase or decrease in terms of average miles (kilometers) driven per year; urban areas are redeveloped; and new areas are opened up. In the end there is no reliable procedure by which to establish what future traffic may be specifically attributed to the proposed highway improvements.

Generated traffic is an accepted concept, but its identification in practice is beyond any acceptable limits of reliability. Consider the 20-year period following the opening of any new or improved highway facility that lowers the running cost of vehicles, traffic accident costs, and travel time by 20 cents per trip the first year. How can estimates

be made for the next year of how many trips will be generated by this 20-cent decrease for the first year? The entire geographical area of n miles^2 (km^2) is involved; land usage, social life, technology, economy, consumption, and transportation of all modes change; and, because of increase in ADT, cost per trip increases. Yet from all of these changes some person is expected to separate total change year by year in number of trips from A to B into trips generated from all other trips. In other words, can anyone estimate the traffic generated today on a given route that was reconstructed 10 years ago, assuming that ADT increased from 5,000 to 9,000?

CONCLUSIONS

If the objective is to calculate the change in consumer surplus, then the areas A_1 and A_2 in Figure 1 give the correct answer. Consumer surplus gained is the rectangle representing price reduction plus the triangle representing value gain to the Q_1 - Q_0 customers. This statement assumes, however, that the price-demand curve is unaltered.

For highways, most analysts follow the same procedure; that is, they add the areas A_1 and A_2 that result from the price-demand curve D_0. To use the full number of trips (Figure 2) Q_1 - Q_0 times price per trip decrease P_0 - P_1 would overestimate consumer surplus by an amount approximately equal to the triangle A_2. This procedure of calculating consumer surplus is correct only if 2 conditions are met. First, Q_1 - Q_0 trips are all induced (generated) by the reduction in cost per trip. Second, the original price-demand curve D_0 still prevails. These 2 conditions are not met, however. Again, if the objective is to calculate the change in consumer surplus, the Q_1 - Q_0 trips must be restricted to generated traffic, and the area A_3 between the 2 price-demand curves must be added to areas A_1 and A_2.

Earlier discussion points out the uncertainties of making any estimate of generated traffic that is separated from other increases in traffic over an analysis period of, say, 20 years. And, of course, area A_3 cannot be estimated because no available evidence exists to establish the location and shape of the D_0 and D_1 price-demand curves. Even if an analyst desired to estimate the change in consumer surplus in accordance with its true concept, any result would be so uncertain that its use would be questionable.

The most uncertain calculations are shown in Figure 3 for making estimates of the changes in consumer surplus on a network basis. For most typical analyses, the consumer surplus change comes from many price-demand curves (Figure 3). Price-demand curves cannot be established for the day the new facility opened to traffic. To establish them for a time 20 years in the future would also be impossible.

All of the traffic increase Q_0 to Q_1 is burdened with the identical trip costs regardless of source, trip purpose, or prior usage of the road system. A procedure of separating generated trips from traffic growth caused by population growth, population migration, and economic changes is questionable. Why base user costs on 100 percent of traffic growth except for generated trips and then use only half the generated trips? Their cost is the same.

It has been reasoned that generated trips could have been taken before the new facility was available, but the reason they were not taken was solely because the cost was higher than the amount the traveler was willing to pay. But on a consumer surplus basis the analyst could use half the trips generated. The consumer surplus procedure, however, gives full acceptance to all other trips. On a cost reduction basis, none of the new trips (generated, population growth, economic change, or social change trips) has experienced a saving in trip cost because no trips were taken at the old cost (cost before improvement). If the analysis for transportation economy can include some new trips (traffic volume growth) over the analysis period, why is it not acceptable to include all new trips?

An analysis of the transportation economy of proposed highway improvements that ignores the consumer surplus concept does not misrepresent the relative economy of the alternatives or their economic feasibility. Introducing consumer surplus in no way gives the decision maker an analysis that is superior to an analysis excluding the concept. The preferred procedure is to ignore consumer surplus entirely and make all calculations on the basis of market cost of transportation. Cost of transportation in-

cludes the priceable costs for motor vehicle running costs, traffic accident costs, and travel time.

The consumer surplus concept is rejected for 2 reasons. First, the economy of highway transportation on which to base a decision of economic feasibility should be based on market-priced changes in consumption of resources rather than the consumer surplus concept of value (willingness to pay). Second, in the analysis, net changes in consumer surplus for highway design and traffic improvements cannot be estimated because there are no price-demand curves.

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DISCUSSION

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Winfrey has presented an enlightening and provocative discussion of several important principles appropriate for an analysis of highway transportation economy. His view that the concept of consumer surplus is not applicable in this context is widely shared by others. For example, Wohl and Martin (28, p. 9) conclude: "It is our view that consumer surplus should not be included in any user tripmaking benefit calculations to be used in assessing the economy of public projects." A less positive view is expressed by Walters (52, p. 56) who states: "The consumer surplus criterion is a tool of analysis that must be handled with care and circumspection."

Most highway economy analyses are structured so that they cannot or do not (and probably should not) account for generated traffic. Thus any elasticity of demand for travel is not considered, and the areas A_2, in Figures 1 and 2, or A_3, in Figure 2, are neither quantified nor used in analysis. The road user benefit that is used in a typical analysis is simply the product of the estimated number of vehicles using the facility or system (Q_0, projected on the basis of assumed normal growth trends) times the estimated reduction in user cost (P_0 - P_1). This, of course, is the area A_1 in Figures 1 and 2. However, area A_1 is also the change in consumer surplus if demand is perfectly inelastic. Therefore, because we are commonly constrained to consider that traffic volumes are equal for all mutually exclusive alternatives, we are in fact using the change in consumer surplus as a measure of economic benefit even though we have had no reason to describe it as such.

On the other hand, let us view a situation in which a determination of consumer surplus is the only practicable method of analysis. Consider the case of a penetration road in a country with a developing economy where the road is to afford access to an isolated area that is either undeveloped or has a subsistence economy. Alternatives, in addition to doing nothing, might include several variations ranging from an unimproved trail suitable only for backpacking to a substantial all-weather road that could carry heavy trucks.

It may be expected that each alternate could be represented by a different supply curve, such as S_a through S_e, as shown in Figure 4. Each supply curve would suggest a different price for transport, P_a through P_e, and would intersect the price-demand curve at a different level of demand, Q_a through Q_e. The extent to which the area served would expand production in response to the substitution of a market economy for a subsistence economy would obviously also vary depending on the use of the highway improvement.

It is also possible that the differing qualities of service from the various transport alternatives are sufficiently representative of different products that demand might be represented better by more than 1 price-demand curve, as Winfrey has suggested. However, we believe that this situation is represented more correctly by a single demand curve and a separate supply curve portraying each of the various alternative types of improvement. Note also that the price-demand curve, rather than being concave upward, is convex to represent the relative elasticity of demand for transport where substitution of a market economy for a subsistence economy is an economically attractive possibility, but demand becomes inelastic at higher levels of production because of natural limitations in productive capability.

In any case, it is evident that the analyst in this situation has little alternative except to attempt to quantify the demand relationships corresponding to several points on the price-demand curve and to use a best estimate of consumer surplus to describe the

Figure 4. Supply curves for highway transportation alternatives.

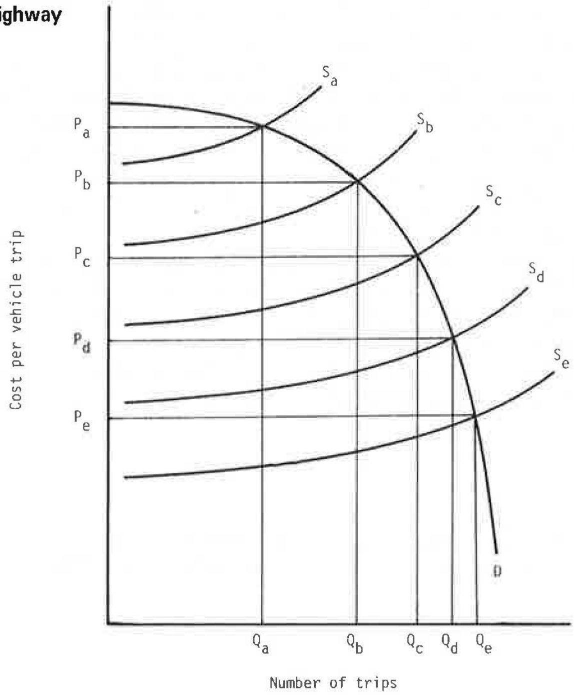
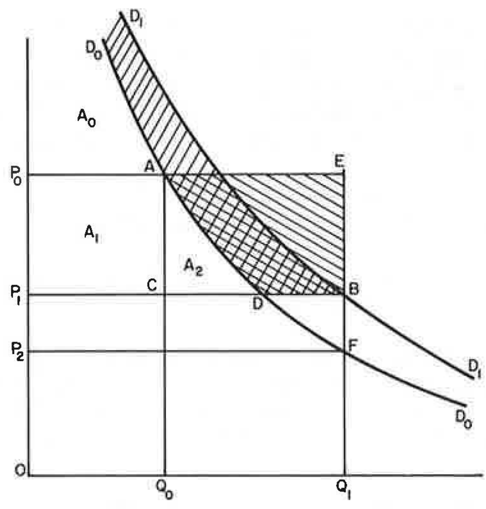


Figure 5. Modification of Figure 2.



benefit. The road user benefit so determined describes a reduction in the cost of transportation even though that transportation might not currently exist because its price is perceived as prohibitive. Nonuser benefits represented by increases in the value of land affected by a transportation improvement are not properly included in an analysis of highway transportation economy, as Winfrey suggested. However, it is reassuring that this benefit, which may be estimated on the basis of precedent for a given country and which has a price determined in the marketplace, should approximate closely the present worth of road user benefits and may therefore serve as a basis for checking the estimated user benefits.

Thus, although it is agreed that the highway transportation analyst typically need not be concerned with concepts of consumer surplus, the analysis will appropriately consider at least the largest portion of a change in consumer surplus. In the less common case of an essentially new highway facility, consumer surplus may represent the only quantifiable benefit, and an understanding of the concept may be essential for an analysis of highway transportation economy.

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DISCUSSION

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We should be very grateful to Winfrey for his clear and penetrating exposé of the concepts embodied in consumer surplus as they should apply to analyses in highway transportation economy. He has highlighted the difficulties of applying the theory in practice and proposed an alternative approach to solving the problem. Winfrey's case against consumer surplus seems to be based on 2 main objections.

1. It cannot be applied in practice.
2. It is not theoretically applicable in any case.

I would like, first, to deal with the second point, which I believe to be unproved and feel to be unprovable. Winfrey states:

> On a cost reduction basis, none of the new trips (generated, population growth, economic change, or social change trips) has experienced a saving in trip cost because no trips were taken at the old cost (cost before improvement). If the analysis for transportation economy can include some new trips (traffic volume growth) over the analysis period, why is it not acceptable to include all new trips?

Winfrey does not believe that one can distinguish between normal and generated traffic, or at least that one can estimate it, say, 20 years after the opening of any new or improved highway facility. I believe that there is a clear definition of generated traffic for the first or the twentieth year after opening the new facility. It is, as nearly every transportation engineer has been taught to believe, the traffic generated by person trips, or goods movements that would not have taken place in the absence of the new facility. Where alternative facilities are being compared, then, it is the traffic that is generated by the superior utility or transport cost savings of the (usually) more expensive solution (the "with" case) that would not appear in the "without" case. There are, of course, many difficulties associated with forecasting the volume of this traffic, but that is outside the scope of the paper.

Winfrey has not given a convincing reason why one should ascribe to all traffic, normal and generated alike, the same level of benefits. It is, of course, a pragmatic way of getting an answer, and, in most cases, it will not seriously misrepresent the relative economy of 2 competing projects. Where the total travel engendered by competing projects is very different or the timing of a single proposal is being analyzed, then there could be substantial misrepresentation of relative economies. Embellishing Figure 2 of the paper somewhat we get Figure 5.

What Winfrey proposes is to equate the area (hatched area in Figure 2) between the 2 demand curves above the line BD with the area ADBE. Although in some cases this may not distort very much the relative economy of projects because the hatched areas are small in relation to total benefits or because they happen to be nearly equal, there seems to be no theoretical reason why the 2 areas should be approximately the same size.

Now let us come back to the first problem, the difficulties of applying the consumer surplus theory to the quantification of benefits and informing for decision making. Winfrey's postulation of a changed demand curve caused by improvements in the utility of travel other than cost savings is very useful in highlighting the difficulties inherent in the estimation of benefits and the definition of demand curves. It is true that there is a different demand curve for each hour of the day and variations of the curve with the season of the year. These can, however, be summed to give a demand curve for annual average daily traffic. Similarly, the demand curve shifts with time (normal traffic increases) so that we have a fresh basis for calculation each year derived from traffic forecasts.

The best theoretical solution seems to lie in efforts to quantify the "unquantifiable" whether it be the misery caused by a road accident or the disutility of noise to residents near a busy airport. Insofar as this can be done we can relate the 2 demand curves D_0D_0 and D_1D_1 and hence fix them at least for 2 points on each curve because the difference in the ordinates for a given value of Q_1 is the value of Q_1 of the improvement in utility from all the previously unquantified sources. Alternatively, one can, though theoretically it may be rather less rigorous, regard these extra benefits as reductions in costs and keep only 1 demand curve; this would be correct only if D_0D_0 and D_1D_1 differed by an ordinate of constant magnitude. When we consider the implication of such a requirement for simplifying the model, however, it should not be too unacceptable because, although people may vary in their valuation of safety, convenience, and the like, we always are dealing with statistical averages in our analyses so that we will, in effect, value each person's noncash benefits at the average figure for the whole involved population. Coming back to Figure 5, then, we can postulate a price P_2 that is P_1 less the cash valuation of noncash benefits. We now are back to the classical uncomplicated picture similar to Figure 1.

Although Figure 1 may be uncomplicated, the actual estimation of the value of noncash benefits is difficult and controversial. A common approach is valuation of the perceived costs that people are prepared to pay for increased utility (such as parking near the office) or to avoid loss of utility (such as traveling by bus rather than by car). Possibly the only, or main, category of cost that yields unsatisfactory values from this approach is the valuation of accident costs because people seem to be prepared, individually, to pay very little to reduce the likelihood of injury or death in an accident, but this pertains more to the application of the consumer surplus concept than it does to the theory itself. At any rate, the valuation of noncash benefits is difficult and can often involve contentious assumptions.

My conclusions, which differ from those of Winfrey, are as follows:

1. Consumer surplus theory is difficult to apply in highway transport economy, but, nevertheless, it is valid.

2. Application of the consumer surplus theory requires valuation of noncash benefits in cash terms whenever possible.

AUTHOR'S CLOSURE

The comments by Spottiswoode are well chosen and appreciated. They also agree with many comments I have received from economists. My major factor in rebuttal is that I am in no way trying to measure change in consumer surplus. I mean to calculate the changes in transportation costs that are priceable on the market because it is a preferred measure of the transportation economy. I reject the consumer surplus unit of measurement because it is a personal value concept, and I wish to quantify the changes by the reduction in consumption of resources for the same equivalent amount of transportation. Furthermore, if one is to adopt the consumer surplus measure of change, one must measure the total change in consumer surplus, including the change above the P_0 price level as well as that between the P_0 and P_1 price levels, for all route segments that experience change in traffic volume or cost per trip.

When one looks at Figure 1, the whole concept of consumer surplus is greatly simplified. An examination of Figure 3 injects many complications. The consumer surplus change wanted is that due solely to the change in price from P_0 to any higher or lower cost per trip. This total change must be estimated for a total geographic area that is affected by the improvement under consideration. There are increases and decreases in both P and Q on segments of the road network. You can have generated traffic on a segment that experiences a net decrease in total ADT. The forecaster takes all factors into consideration that relate to traffic. This includes land use changes far and near. An estimate of traffic with and without the proposed improvement includes a composite of changes of such complexity that generated traffic caused solely by the change in the market price level of a trip is not identified.

I am not trying to ascribe gross benefits at all. I merely am trying to determine the change in consumption of resources, or the economy of the transportation with and without the proposed investment. There is nothing in my paper that says I am equating the hatched areas mentioned by Spottiswoode. My claim is that the 2 price-demand curves cannot be established for want of quantification of Q trips at a range of values of P. What is wrong with this procedure?

I agree that the price-demand curve should be drawn on a basis of averaging out daily changes and even monthly changes. But, on the other hand, my reference to these changes is to point out that the price-demand curve continually changes and that even to draw any curve without knowing more about the price relationships than we now know is rather hopeless. When the highway users at peak hours are paying a higher cost per trip and are making more trips, they are certainly on a different price-demand curve than they were on at low hourly traffic volumes. And some changes in network travel come under conditions of increased P unit cost.

The discussion offered by Spottiswoode on quantifying the unquantifiable pertains to the user factors that are not quantifiable and are not priceable on the market. Such factors are not included in my calculation of the economy of transportation. But they do affect the user's choice of route and the location and shape of the unknown price-demand curve. As stated in my paper (this point, however, was not in the version available to Spottiswoode) in the analysis for transportation economy, the analyst is forced to use cost of trips based on market prices of vehicle use, traffic accidents, and value of time, none of which makes any allowance for outside values of the personal preferences of the road users. Therefore, the analyst cannot include in his or her calculation the added value that the drivers may attach to nonmarket factors.

Perhaps I am not well versed in the consumer surplus concept and price-demand curves, but I cannot see how 2 points can be established to enable a curve to be drawn between the 2 price levels. On the basis of market pricing of user costs, point A on curve D_0 and point B on curve D_1 are the only points that can be calculated and they are on separate curves.

The discussion by Carstens and Kannel is realistic; it is the best I have received in the many private conversations and discussions that I have had on the subject in the last 2 years when and where I have informally presented my views. But here, again, Carstens and Kannel neglect some factors.

I appreciate that Carstens and Kannel acknowledge that, in most ordinary analyses

of the economy of transportation alternatives, the consumer surplus need not be computed (even if it could be done).

My concept and approach related to the penetration road in a developing country again has no reference to consumer surplus. First, consumer surplus cannot be established because of lack of price-demand curves, and, second, consumer surplus is not the determining factor on which to make the decision to build or not to build. There are just 2 factors of consequence (not considering the foreign trade balance, the shifting of population, and social aspects of the project if it were constructed).

First, the economic evaluation of the penetration road depends on the development of economic production, either by bringing new land into production or by harvesting local natural resources. The cost of the penetration road must be charged along with other economic costs to the harvesting of the new production and not as an improvement in transportation. The economic value of the new production is its value on the market less its cost to produce including the cost of the penetration road. The cost of the railroad to the iron ore deposits in western Australia is chargeable to the cost of harvesting the iron ore in the same way as the cost of the mining operation itself. This controversial subject, now that it is made public for the first time, should be discussed by both engineers and economists so that we will be better informed and perhaps agree on a procedure in cost-benefit analyses that gives acceptable results with reasonable effort. But I would like to know why others claim that the consumer surplus approach is better than my economy of transportation approach. So far, no one has informed me why the decision maker should prefer the evaluation of the change in consumer surplus to my quantification of the economy of transportation.

Second, the economy of road design, or project formulation, must be analyzed. The penetration road, assuming that it is economically justified on the basis of the market value of the production from the land, must be designed for the expected traffic loading in the same way that all engineering designs are formulated. That is, one must design the system for the lowest total cost over time and see that it adequately provides the safety level and quality of transportation desired. This step in no way depends on consumer surplus or the economic productivity gained as a result of the penetration road. It is simply a straightforward engineering process based on economy of design. It is the same as the process that a structural engineer uses to try out several locations and geometric shapes and materials for a bridge across a stream.

I should like to have economists and the doubting engineers study the Winfrey approach with the view that perhaps it is acceptable, rather than have them try to prove it is wrong. Except for Carsten and Kannel, many commentators have used the latter approach and have arrived at a negative conclusion without endeavoring to determine whether the approach will give acceptable and usable answers to the decision maker. My proposal does not encompass all the consequences that result from a highway improvement, but only that directly affecting the cost of transportation that can be market priced. All other factors are handled separately by whatever device is chosen by the decision maker in a separate report.

When I first came in contact with the consumer surplus concept, I accepted its logic and its application. But, after several experiences and much study, I concluded that the consumer surplus concept cannot and should not be used in analyzing the economy of transportation as applied to proposed highway improvements.

In the decision-making process, why is the measure of transportation economy proposed in this paper not an acceptable procedure? If it is not acceptable to the decision maker, why is it not? If it is not, why is the consumer surplus calculation, even if it could be calculated for the highway network affected, to be preferred?