PAPER TITLE (90 Characters Max)	**The proper use of Consumer Surplus for the evaluation of road projects in developing countries**		
TRACK			
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KEYWORDS:

Include up to 5 keywords

Economic analysis, consumer surplus, HDM-IV

ABSTRACT:

Since Dupuit (Dupuit 1844) there is a consensus to measure the benefits and the willingness to pay of transport project users through the use of the concept of consumer surplus, calculated as the difference between what the users are willing to pay, which is expressed by the demand curve, and what actually are they paying.

For road projects, both capacity expansions or infrastructure improvements (paving, repaving, etc..), this procedure is used as a standard, and is included in several widely available computer systems as HDM-4. This paper analyze in detail the use of consumer surplus for quantifying the benefits of transport projects and in particular distinguish between sensitive, financial and economic costs, to be taken into account. This work perform a review and critique of a number of inconsistencies that appear regularly in studies in this field and in particular in the application through the HDM-4 in which it was found that contradicts the theoretical foundations. The paper concludes with guidelines for the proper employment of the consumer surplus on the basis of appropriate microeconomic assumptions.

The proper use of Consumer Surplus for the evaluation of road projects in developing countries

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APPROACHES TO THE EVALUATION OF TRANSPORT PROJECTS

The procedure for economic evaluation of a road project is based on the comparison of the resources utilized (construction and maintenance) with the benefits generated by the project to the economy as a whole. One of the main points that arise in this analysis is the problem of how to estimate these benefits in order to properly evaluate the project.

As a first conceptual point, it is important to emphasize that any transportation project impact positively on the economic growth of the country, even if may be in different degree. In this line, it is important to properly assess the benefits of the project to correctly compare investment alternatives.

The first approach is a purely economic standpoint: measure all the resources that the economy had "before" and "after" the project and calculate its difference in economic terms to estimate the value added. This process is described by Squire et al. (1975): "Whatever the nature of a project, its implementation always reduce the availability of inputs ("consumed" by the project) and increase the number of outputs ("produced" by the project). Without the project, the availability of these inputs and outputs for the rest of the economy would have been different. Examination of the difference in the availability of inputs and outputs with and without the project is the basis of the method to identify costs and benefits."

However, this procedure is difficult to realize in practice, so that from the article written by J. Dupuit in 1844 (Dupuit 1844) there is a consensus to measure these benefits and the willingness to pay of consumers, through the use of the concept of consumer surplus.

PRICE, SENSIBLE COST, FINANCIAL COST AND ECONOMIC COST

In the calculation of benefits from the economic point of view, indirect taxes (taxes other than income taxes) should be excluded in all prices since are additions to the economic value of the goods or services that do not represent real demand, but are just a transfer of resources between the beneficiaries of the project to the Government.

There are other distortions in the pricing system such as subsidies or distortions caused by imperfect competition in some markets, which should also be excluded, since decisions on prices set by institutional forces can generate distortion in the results of the cost analysis. To solve these problems, we commonly use shadow prices defined as:

Economic Cost = market price (financial cost) - transferred charges (ie taxes) + effects of other distortions (ie subsidies).

In the case of goods that are offered for imports and exports, prices must be taken at international prices, adding direct taxes minus costs of freight, insurance and transportation. Regarding labor costs, it must take into account the economic opportunity costs, considering the unemployment or underemployment rates.

Having said this, we can argue that economic and financial costs may be very different, depending on the characteristics of the economies and may have very different behavior. We proceed analyzing the willingness to pay of consumers and it relationship with costs.

THE WILLINGNESS TO PAY AND THE DEMAND CURVE

As stated in the "User Benefit Analysis for Highways" manual (AASHTO 2003), "fortunately, economists have shown that people express how much they want something, demonstrating a willingness to pay for it," representing this a quantitative measure of welfare. This is the value perceived by the user that uses to make economic decision and is called sensible cost.

Once is known the willingness to pay of users, we can define the demand curve as the mathematical representation of the relationship between willingness to pay (sensible cost) and the quantity demanded, keeping everything else constant. This curve has a negative slope, since quantity and price are inversely related (law of diminishing demand) primarily by the income and substitution effects.

The vertical axis can be interpreted as the highest price a user or a consumer is willing to pay for an additional unit of good. The negative slope of the curve is also explained by the diminishing marginal returns of the utility of the good, as an additional unit is valued less by each consumer than the preceding unit.

Since the demand curve shows the relationship between the market price of a good (willingness to pay) and the quantity demanded, it can be inferred that the areas below represent the total amounts spent or saved by the consumers.

In a competitive market, consumers will pay the market price (P*), consuming an amount X*, so the consumer spending is P*X*, identified as the dark shaded area “A” in Figure 1. The net benefit for the consumers is calculated as the difference between the area below the demand curve for X* units (total area A + B) less the consumer spending (area A), represented in dark grey in Figure 1. This difference is defined as Consumer Surplus, since is the additional benefit for the consumers that were willing to pay a higher price than P* for the good, but since they are in a perfect market, they finally pay P*.

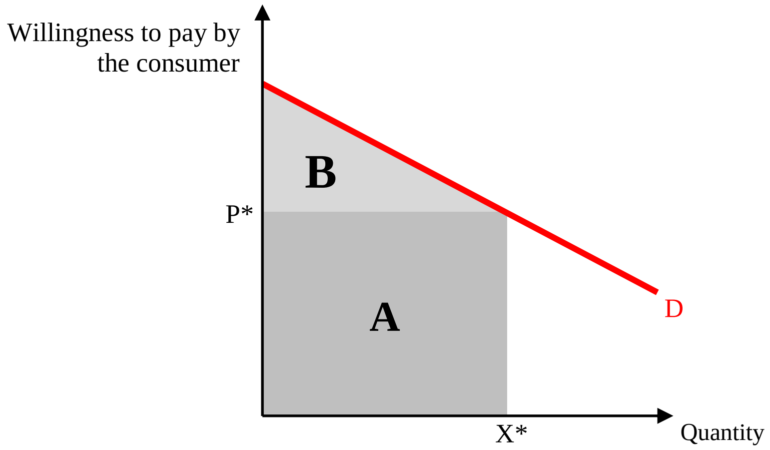

Figure 1: Demand curve

To evaluate a transportation project from this approach, we should use the willingness to pay as a method to assess the benefits and the opportunity costs to measure the resources required to implement it.

Changes in consumer surplus can be used in many cases to evaluate the benefits of a political decision, because they are a reasonable measure of the increase in benefits received by users. However, by definition, the calculation of changes in consumer surplus should be conducted on the demand curve, which means that prices or costs used should always reflect the willingness to pay of users in the market (sensible cost) and should not be used economic costs.

SENSIBLE, FINANCIAL AND ECONOMIC COSTS IN TRANSPORT

In the case of transport, to analyze any project, it is important to identify that the willingness to pay of users is given by the so-called "sensible" cost, which is the one perceived by the user to make his decision. The financial cost however is the cost actually incurred by the user (which may be different from the sensible, for example by the subjective assessment of the time as a function of the day of the week or the time of the day or because the user does not make his decision considering certain costs in which he actually incurred). Finally the economic cost is the measure of the consumption of resources of the whole economy used in transportation, and is different of the financial cost due to the different distortions that are present in real situations of imperfect markets.

In the hypothetical case where there are no distortions and users react to what they perceive only financially (without other subjective alterations), sensible, financial and economic costs would be the same, and in theory the calculation of benefits by purely economic computation would be the same than the calculation trough the consumer surplus.

Nevertheless, in general in transport economics, sensible costs and financial costs are different due to the nature of decision making by consumers and their perceptions. In addition, virtually all economies suffer distortions (subsidies and indirect taxes), so there are differences between financial and economic costs.

Therefore, we conclude that in the case of transportation, all costs identified are in general different and eventually they may be significantly different, depending on the context.

CALCULATION OF BENEFITS WITH CONSUMER SURPLUS

Developing this second alternative, in the case of road projects it is usual to identify three types of traffic: normal traffic, induced traffic (also called "generated traffic" according to PIARC 2000 and Boardman et al. 2011) and derived traffic.

Normal traffic exists even without the project and is independent of it.

Induced traffic is the new traffic generated by the reduction of operating costs and vehicle travel times thanks to the project.

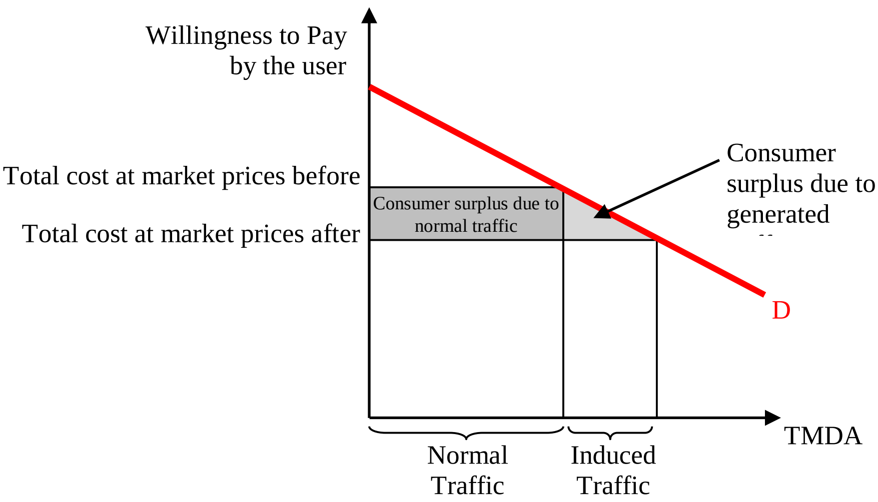

Figure 2: Consumer surplus in road projects

Finally, **derived traffic** is product of the redirection of traffic into the project from other modes or routes (ie an alternative route) produced by the decrease in the transport cost that makes the users to change their modes or route. The benefit generated by this derivation is radically different from the other two, and its calculation should take into account the original cost (in the other transport mode or alternative) and the difference with the transport cost at the project. In this paper we will focus on the benefits due to normal and induced traffic, but its considerations are also valid for the corresponding derived traffic.

As it was previously stated, the objective of the economic evaluation of a project is to asses if the benefit produced by the project is higher than the investment. Given the definition of the types of traffic and taking a road project as an example, as was mentioned, there are two alternatives for determining the benefits of the project and ultimately this convenience: to do it from economic values or to do it from the willingness to pay of the users.

In the first case, the analysis is performed adding the benefits of the project in economic terms, seeking to assess the contribution of the project to the country's economic growth. For the calculation of these benefits should be considered for each user, the costs of transport in economic terms before and after the project, and take into account the normal and the induced traffics to integrate the total cost, and then add the difference in costs in the case of derived traffic, depending on the previous alternative route or mode.

In the second case, the definition of economic convenience of the project should be done only in terms of willingness to pay for road users facing their perception of the transport costs before and after the project. This should not take into account the economic costs of users, but the cost perceived by users (their willingness to pay) and how it shifts the equilibrium through the demand curve.

Applying the basic microeconomic concepts, it would be needed to know the demand curve (or at least some points) and based on that, knowing the cost reduction perceived by users because of the project, it is possible to calculate the consumer surplus.

The important thing here is to recognize that due to the very definition of the demand curve and its components, the price to calculate the consumer surplus should be measured by the willingness to pay of users, and not from economic costs.

So, what happens if we try to use economic costs on the same demand curve? The result is that the estimated benefits and the alleged consumer surplus are not such and could be very different from real ones. Moreover, to compute the amount of traffic induced we use the definition of the demand curve by looking to the intersection point of the demand curve and the "Willingness to pay with Project" (transportation cost perceived by the user with the project)

By using Economic Cost in the demand curve, there are two different situations occurring: looking the intersection of the economic cost and the amount of (correct) induced traffic: the point will not be on the demand curve (Case 1). On the other hand, if we intersect the demand curve and the Economic Cost, the point will not corresponds to the (correct) induced traffic (Case 2).

For the case in which the "Economic Cost with Project" is less than the willingness to pay for the new project, the results of the analysis of the two Cases (1 and 2) are analogous in the sense that do not reflect the real situations of the definition of the consumer surplus.

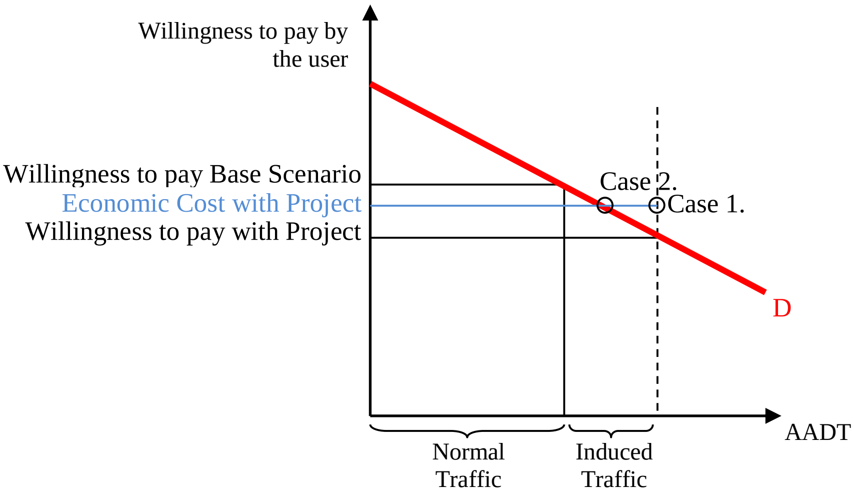

Figure 3: Incorrect use of Economic Cost on the demand curve

CALCULATION OF BENEFITS IN PRACTICE

Then, how this calculation is performed in practice? To answer this question, we analyzed the process of calculating the benefits of projects using the software HDM-4.

As described in Chapter G1 "Economic Analysis" of Volume 4 of the "Analytical Framework and Model Descriptions" of HDM-4, the analysis is done in economic terms. The procedure compares the investment options (economic costs of the project for the road agency) and the benefits, calculated also in economic terms.

The composition of the benefits is:

a. Savings in operating costs of motor vehicles.
b. Savings in travel time costs of motor vehicles.
c. Savings of time and operating costs in non-motorized vehicles.
d. Reductions in accident costs.

Finally, there are others exogenous costs and benefits to the project itself, which also affect their economic evaluation.

By calculating this components, it is possible to compute the economic indicators for the decision: NPV, IRR, cost / benefit ratio and benefit of year one.
For this paper analysis, the idea is to identify how HDM-4 calculates the savings in the first three items (a, b and c), which are the benefits of the reduction of the operating cost of the project. The following equations were written in general terms: "m" represents project scenario, "k" are the types of vehicles and "s" the specific sections of the project.
So, HDM calculates the benefits of point a) "Savings in operating costs of motor vehicles", as:

$$\Delta VOC = \left[\Delta VCN_{(\mathrm{m-n})} + \Delta VCG_{(\mathrm{m-n})}\right] \quad (1)$$

Where:

$$\Delta VCN_{(\mathrm{m-n})} = \left[\sum_{s}\sum_{k} TN_{nsk} * UC_{nsk} - \sum_{s}\sum_{k} TN_{msk} * UC_{msk}\right] \quad (2)$$

and

$$\Delta VCG_{(\mathrm{m-n})} = \left[\sum_{s}\sum_{k}\left\{\frac{1}{2} * [TG_{msk} + TG_{nsk}] * [UC_{nsk} - UC_{msk}]\right\}\right] \quad (3)$$

Where:

$\Delta VOC_{(\mathrm{m-n})}$: Savings in vehicle operating costs due to total traffic of the investment "m" for the baseline scenario "n".
VCN_{ms}: Annual operating cost per vehicle due to normal and derived traffic on section "s" with the investment option "m".

TN_{msk} : Normal and derived traffic, number of vehicles per year in both directions in the section "s" of the road with the investment option "m" for the type of vehicle "k".

UC_{msk}: Average annual operating cost per trip-km on the section "s" for the vehicle type "k" with the investment option "m".

$\Delta VCG_{(\mathrm{m-n})}$: Operating benefits of vehicles due to the traffic generated from the investment "m" the baseline scenario "n".

TG_{msk} : Induced (generated) traffic in number of vehicles per year in both directions in the section "s" of the road with the investment option "m" for the type of vehicle "k".

These are general expressions that may be used to compare different scenarios between each other or to compare each one to the Baseline. That is why, for example, there is a term for the induced traffic (generated) without project that by definition is zero (no project -> no induced traffic).
Beyond this, it was not possible to have more information about the exact theoretical basis of these formulas. During the analysis, we proceeded to the formal consultation to the software support, without having received any response to the date of this submission.

Trying to make an assumption, from the use of the coefficient "1/2" in the expression (3) of the benefits of the induced traffic (generated), it appears that this method would come from a calculation of consumer surplus, and this term represent the triangular area B of Figure 1. This was not stated in the HDM manual, as was said before, but the analogy is clear. The problem is that all the cost included in the equations are economic costs, so the trapezoid calculated in the expression it is not really a calculation of the area under the demand curve, but a calculation of a value called "$\Delta VCG_{(\mathrm{m-n})}$" that, in the best case, could be considered an approximation of the benefits. The problem is that, as was said before, there is nothing that guarantees that the error is bounded or that it could be possible to estimate an a-priori tendency of the direction of the error, because depends on the characteristics of the economy and the project.

This methodology is then repeated for calculating the benefits of the points b) and c) with the corresponding terms.

The main distortion of the analysis is when computing the induced traffic benefits, because for the normal traffic, the traditional economic assessment could be possible, even if difficult, but for the induced traffic the situation is more way complex. In fact, for this case, it could be possible to argue that induced traffic could generate additional economic benefits that are not taken into account in these formulas for the economy as a whole, such as the generation of additional jobs. In fact the link between the benefits of normal and induced traffic may not be bounded in any direction, since it might influence aspects of the economy that go beyond the road project.

This definition of demand curve is clear in the manual "User Benefit Analysis for Highways" of AASHTO, which states that economists define the demand curve as the relationship between willingness to pay of the users and the actual amount of travel between A and B users would be willing to perform at different levels of cost per trip. The difference between what the users (in total) have been willing to pay and what they actually pay, is captured by the consumers as a surplus of well-being, and hence is called consumer surplus (AASHTO 2003).

In short, the proper use of consumer surplus for the calculation of benefits in economic evaluations of road projects, require us to move always in the world of willingness to pay, then taking this surplus as dispositions to pay by the users. Beyond this, is not possible to mix the concepts between the analyses of the aggregate economy and the consumer surplus computed using the demand curve, because using the economic cost to compute the consumer surplus goes against the very microeconomic definition of the demand curve.

CONCLUSIONS

The main conclusion of this work is to highlight the importance and the need to study properly the methodology of calculation of benefits from the economic point of view to correctly analyze the economic multiplier effects that matter in assessing the benefits of induced traffic in terms of added value.

On the other hand, addressing the evaluation of the benefits from the perspective of the willingness to pay, it is needed to develop consistent methodologies to properly consider sensitive costs of road users (that work as prices) from empirical studies, to identify components of the costs with which people actually make decisions and drive the user willingness to pay for transportation services.

Finally, we highlight the importance of deepening the study into the foundations for the calculation of the benefits of induced traffic according to the methodology of the HDM-4 to verify the degree of approximation based on the theoretical foundations of their definitions.

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