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Under-evaluation of projects and traffic models

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Abstract

Transport infrastructure projects are based on ex ante cost benefit analysis. Traveler surplus often represent a large part of a project's global benefit. The assessment of these traveler benefits, or surplus, as recommended in official French guidelines, is based on average benefits for a project. But in fact, benefits are widely distributed among individual travelers and discreet choice models enable us to have access to this distribution. The aim of this paper is to show that using the surplus given by discreet choice models leads to higher amounts of benefits compared to "classical" methods when the project has a high cost for users. The example of tolled highways is simulated in the paper. Pros and cons of the different methods are given before suggesting recommendations.

Under-evaluation of projects and traffic models

1. Introduction

Estimating the discounted benefits generated by building a new infrastructure or by commissioning a new mode of transport is one of the classical calculations of socioeconomic evaluation made obligatory by official texts[1]. In the vast panoply of means of creating and destroying value taken into account to achieve this, we know that the benefit that generally weighs most heavily is that which benefits the consumers, that is to say their surplus in the meaning of Jules Dupuit (1844). This non-commercial item is measured in monetary units thanks to his genial intuition which in fact forms the basis of economic calculation. It consists in assuming that the collective utility of a structure whose use is free can be measured in monetary terms by considering that all the consumers would be ready to pay for said use (thus by assuming that one could obtain from each consumer the exact amount of a toll above which they would be discouraged from using the structure).

Thus, between an initial state 0 of transport supply and the final state 1 which has to be evaluated, the variation of the consumer surplus, formalised according to current writing, is the following:

$$\Delta S = -\int_0^1 T(p).dp$$

with *T* being the quantity of transport service consumed as a function of price *p* (a price that is a *generalised cost*, according to contemporary estimations, based on revealed preferences of the consumer that includes non-monetary items such as time and comfort). Thus, we find very exactly the same ingredients as in Dupuit's recommendation. The only difference between his formula and the contemporary approach consists in establishing this result with a mathematical formulation and integrating it in the welfare theory of public investment. Many years after the founding article this formalisation allowed Jacques Lesourne (1972) to perform the mathematical demonstration of the fact that this variation of consumer surplus is a component of the variation of public utility.

For Jules Dupuit, the full measure of this variation of social utility is obtained by adding to this creation of value for the benefit of consumers, the other creation of value embodied by the possible receipts generated from the structure in question (in the case where it is subject to a toll) and, of course, by discounting the depreciations of value in the form of investment and operating expenses. We know that these cost-benefit calculations have been constantly improved and incorporate a growing number of effects outside the commercial sphere: these mainly concern safety and the environment. The fact remains that in the framework of socioeconomic evaluations, consumer surplus generally represents the largest share of the benefits of the project evaluated.

It is therefore an item having an impact in the evaluations that are considered to shed light on the decision to invest. More specifically, when referring to recent texts (Ministry of Public Works, 2004 and 2005, and 2014), it can be seen that the Net Present Value (NPV) per public Euro spent becomes important in the ranking of projects, in the image of what occurs on the international level with the idea of *value for money*. Thus, the challenge of performing a pertinent evaluation of this surplus cannot be considered negligible in projects for which the consumer surplus amounts to more than half of the NPV (Chevasson, 2007).

[1] In particular, in France, the "framework instructions" of the relevant ministry that have been regularly updated since the 1960s, the last update occurring on 16 June 2014 and which several laws, like the LOTI of 1982, have made compulsory.

The objective of this article is to show that this evaluation can be considerably reduced according to the method chosen to evaluate the surplus, and more specifically according to the modelling of the supply and demand functions.

The two possibilities for calculating consumer benefits are described in section 2, as are the advantages and disadvantages of each of these methods. Section 3 presents an application for two types of model used everywhere in the world and especially in France (SETRA, 2010). Section 4 recalls the conclusions of the example used and proposes several recommendations for evaluating projects.

2. Methods of evaluating surpluses and traffic models

As in many countries, it has become common practice in France to officially formalise methods of evaluating transport policies. For more than 40 years this formalisation has been regularly updated by the Ministry of Transport, on the basis of research work and technological developments in evaluation methods. The modalities of calculating consumer surplus were set out in the Government Instruction issued on16 June 2014 relating to the evaluation of transport projects, completed by a technical note from the “General Division of Transport and Marine Infrastructures” relating to the evaluation of transport projects (2014).

It includes very classical definitions of surpluses. For example, when building a new structure (road, railway line) and part of the traffic that used the old itinerary takes the new one, if the average generalised cost of the old itinerary is equal to C_1 and it becomes C_2 on the new one, and if the traffic transferred is equal to T, the consumer surplus is equal to $T(C_2 - C_1)$.

When an improvement in service quality generates additional traffic ΔT, the surplus generated is generally estimated as being equal to $\Delta T\ (C_1 - C_2)/2$. What is more, if this transfer of part of the traffic reduces the generalised costs of the initial itinerary by decongestion, the result is an additional surplus for the consumers who do not change their itinerary.

We propose to show that this classical formulation of variations of surpluses takes imperfect account of reality. Two methods of estimation are required to distinguish this.

2.1. Calculation of average benefits

This is the method recommended in France by the “Framework instruction relating to the modalities of evaluating major transport projects” (2007). In this, the socioeconomic calculation performed uses reference values (the definition of which is given further on) to monetize the benefits provided by transport models. Figure 1 summarises this calculation schematically.

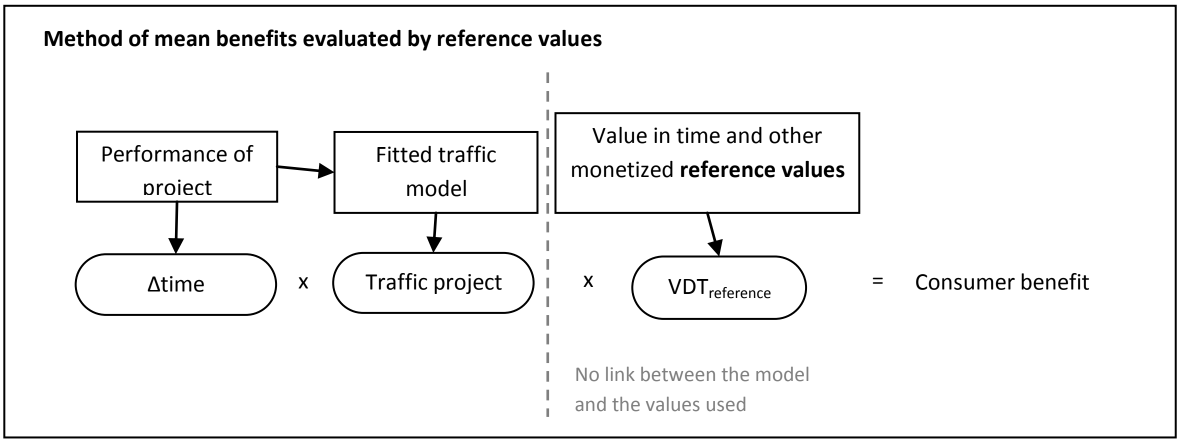


Figure 1: Method of mean benefits evaluated by reference values.

The advantage of this method is its simplicity, especially in that it permits comparing projects with each other between all individuals and all territories. It also has the advantage of not depending on the modelling method chosen. Works have shown that several types of model with several sets of parameters can reach the same results in terms of traffic levels, although the parameters used can differ, notably in terms in the value of time (de Jong *et Al.*, 2007; Jeannière *et Al.*, 2010). The fact of separating the monetization of the effects from the modelling process therefore suggests better comparability between socioeconomic evaluations.

However, this method implies differences between the modelling of behaviors and the evaluation, in particular for the value of time. The results of the evaluation differ in this case from the real value created. For example, a project that has a high saving in time for a high toll will be used by individuals very willing to pay for it. However, the calculation of the mean benefit may result in a negative consumer benefit if done on the basis of mean values, whether reference values or those resulting from a traffic model. Let us assume that the project ensures a time saving of 6 minutes for a toll of €1.5 and that the reference time value used is €10/h. The benefit A of the consumers is given by:

$A = traffic_{project} \text{ x } (VDT \text{ x } \Delta t_{project\text{-}reference} + \Delta cost_{project\text{-}reference})$

$A = traffic_{project} \text{ x } (10 \text{ x } 6/60 - 1.5)$

$A = - 0.5 \text{ x } traffic_{project} < 0$

Thus, we obtain a negative consumer benefit whereas the traffic model predicts non-zero traffic on the project, meaning that certain consumers obtain a benefit in comparison to the alternative itinerary. Indeed, in this numerical application, all the consumers whose individual time value is higher than €15/h obtain a (positive) benefit from the project. The behaviour of the consumers therefore reveals a "value" different from that measured with the mean values, whether reference values or not. In addition, the same difficulty occurs when using a single value to deal with two regions with different incomes: this apparently fair choice leads to an error in the measurement of the values created.

This risk of error should nonetheless be seen in relative terms. The reference values are nonetheless defined "as close as possible to individual preferences". The Boiteux report (2001) asserts the following: "*The expression "reference value" is found in different reports of the plan. Although this notion applied in the past to the monetization that the government, in all its wisdom, promulgated for the good of its citizens without necessarily having to agree with their viewpoint, in this case it is a value that workgroups [the BOITEUX commissions] have attempted to set by analysing people's behaviour … We find here a very classical problem in public economics relating to the social welfare function … the latest works have taken the option, whenever possible, of basing the production* *process underlying these values on observations of behaviours, so that the reference values are not completely disconnected from what behaviours reveal about economic agents”*.

These elements allow distinguishing the first of the two disadvantages mentioned above. Thus, the reference values are generally segmented, for example, as a function of distance, mode of transport, or motive. The modeller can therefore segment demand to get the average values used for the evaluation to correspond as well as possible with the values revealed by behaviors.

Furthermore, the issue of the hypothesis of the optimal distribution of incomes, without which the consumer surplus is not additive, remains unanswered. Drawing together the reference values and the revealed values closer together naturally favours useful investments with the highest incomes. But this question evokes raises the need to take into account redistribution, mentioned in the works of Bonnafous and Masson (2003) regarding spatial equity and of Raux et al.(2007) regarding considerations of vertical, horizontal and spatial equity. These works plead in favour of a certain amount of de-aggregation, making it possible to monetize the benefits differently, and better identify the winners and losers. In response to these difficulties, recent instructions from the French administration recommend performing a sensitivity test on the results of the socioeconomic calculation by taking into account the time values from the model rather than the reference values (Ministry of Sustainable Development, 2014). This test is summarised in the flowchart below (figure 2).

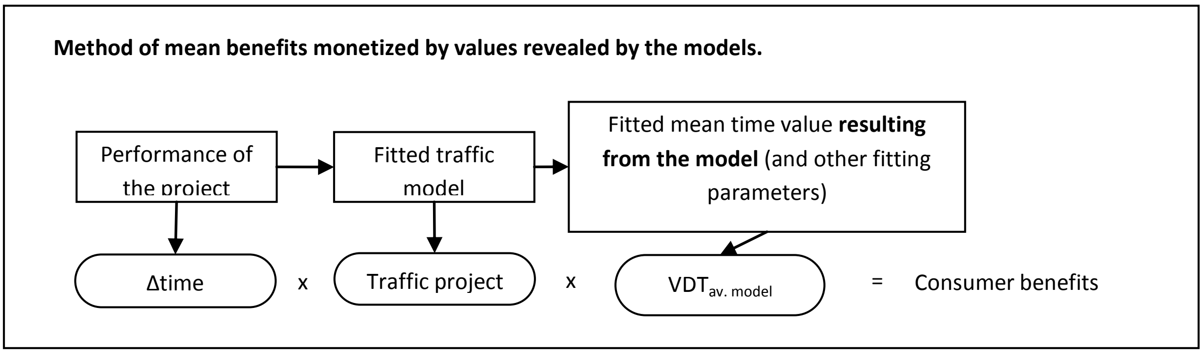


Figure 2: Method of mean benefits monetized by values revealed by the models.

This method improves taking behavior into account in the calculation of benefits in comparison with the previous method. However, although it uses values resulting from average models, it can lead to the same errors as the approach by reference values. By pursuing the previous example, and assuming that the average time value revealed by the model is €12/h, we obtain:

$A = traffic_{project} \times (VDT_{revealed} \times \Delta t_{project-reference} + \Delta cost_{project-reference})$

$A = traffic_{project} \times (12 \times 6/60 - 1.5)$

$A = -0.3 \times traffic_{project} < 0$

However, the traffic model predicts non-zero traffic on the project (41% for a simple Abraham road-highway competition model), meaning that the consumers will obtain a benefit. Indeed, with this numerical application, all the consumers whose individual time value is higher than €15/h obtain a positive benefit from the project. In practice, if the benefits of the consumers of the competing itinerary are omitted and we consider that its performance is the same between the reference situation and the project situation the average benefit becomes negative immediately the market share of the highway falls below 50%. Indeed, a market share of 50% indicates that the generalised cost of the project is equal to the generalised cost of the reference (taken as equal to the generalised cost of the free alternative itinerary in this simplified example). The examples of section 3, based on a more complex calculation integrating several iterations of assignment, suggest equality for a market share of the highway in the region of 30% to 40%.

As stated above, this approach using revealed values was recommended as a sensitivity test in the official instruction on evaluation updated in 2007[2]: *"The calculations will be performed with normalised time values, representing a synthesis of behaviour values resulting from the best available traffic studies. The aim of this normalisation is to ensure the comparability of the profitability studies of different projects. These values can differ from the time values used in traffic models to establish the mobility forecasts of the project being evaluated. As a variant, it is possible to perform profitability calculations with the time values used in the traffic study."*

However, it is clear that this suggestion concerns the use of average time values revealed by the models and not the utilisation of the statistical distribution of these values which will be presented in the following paragraph and which one might imagine greatly improves the consistency between the model forecast and the socioeconomic calculation. (Meunier, 2014).

2.2. Calculation of the distributed benefits resulting from the models

The normative or revealed values mentioned previously are items for measuring the social welfare function for gains in time and comfort. However, we accept that the choices are based on functions of individual utility that vary considerably according to the individual and circumstances. For example, tolls may or may not be reimbursed by employers, the time values depend on the motive of the trip, incomes are a very important factor, etc. Attempts are made to integrate this dispersion of preferences in the formulation of discrete choice models.

Utility is therefore expressed as a deterministic component (observable and measurable) and a random component:

$$U_j^i = u_j^i + \varepsilon_j^i$$

Where:

U^i_{j} represents the utility for individual i of choice of option j
u^i_{j} represents the deterministic component (measurable and observable) of the utility. In the absence of segmentation, this component is the same for all the consumers,
$\varepsilon^i_{\mathrm{j}}$ represents the random variable, with a zero-mean value for the whole population.

Consistent with standard theory, individuals will choose the option that maximises their utility. Thus, to simplify a choice between two itineraries, if we consider $a^i_{2,1}$ the benefit obtained by itinerary 2 in comparison to itinerary 1 for individual i, then

$$a_{2,1}^i = u_2 - u_1 + \varepsilon_2^i - \varepsilon_1^i$$

Individual i will take itinerary 2 if it gives them a benefit in comparison to 1, thus if $a^i_{2,1}>0$. This condition is written as follows:

$$\varepsilon_2^i - \varepsilon_1^i > -(u_2 - u_1)$$

Variable (ε^i_2-ε^i_1) follows a zero-mean probability distribution. Let $x= \varepsilon^i_2-\varepsilon^i_1$.

[2] In Appendix I relating to the reference value of indirect and non-commercial effects.

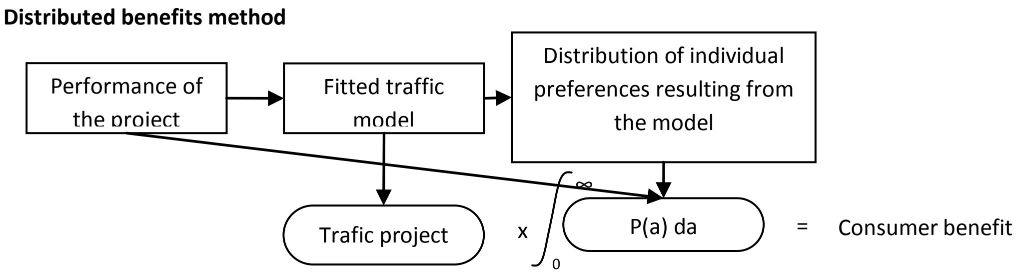
The proportion of traffic on itinerary 2 in comparison to 1 amounts to estimating that probability $P(x>-(u_2-u_1))$, that is to say estimating the probability that x is greater than the mean benefit.

A large number of discrete choice models can be used to predict the assignment of traffic between itineraries and competing modes, based on various hypotheses relating to the type of random term ($\varepsilon^i{}_2-\varepsilon^i{}_1$). Those used most frequently are:
The Logit model,
The Logarithmic Logit model, also called Abraham's law in the literature,
The time-cost model,
The Probit model.

We will not deal with other types of model, although certain of them are more often used in urban areas (CERTU, 1998, Bonnel, 2004). As mentioned in the introduction, in this work, we focus on the logarithmic logit and time-cost models used by the scientific and technical services of the French government to evaluate projects.

The literature contains a large number of works on Logit models. Small and Rosen (1981) explained the conditions in which economic calculations could be adapted to the case of discrete choice models. These conditions, like the constancy of the marginal utility of incomes, have been studied in-depth by many authors (Bates, 2003 and Jong *et al*. 2005), likewise for the hypothesis of the independence of random variables (Zhao, Kockelman, & Karlstrom, 2008). Thus, under the "right conditions", the surplus can be expressed simply as a logsum difference (De Jong *et al*, 2005).

Although the theory has been known since the end of the 1970s, cases of the concrete application of this method have only been reported since the beginning of the 2000s, since the use of discrete choice models became generalised due to the availability of dedicated software on the market. In particular this calculation aid spurred Dutch and American research work which proposed an estimation of consumer surplus using the method of benefits distributed by log-sum difference. The aim of this communication is to show that the results depend on how the models are formulated, a factor that reduces the possibility of comparing projects.



Where a is the individual benefit and P(a) the probability of this benefit. The probability distribution P(a) is defined by the traffic model as a function of the performances of the project and all the fitted parameters.

The fraction of traffic that estimates that its benefit falls between a, and a+da, leads to a variation of the surplus:

dS = P(a) da

Figure 3: Distributed benefits method

Note that this method has the following three advantages:
- The evaluation of consumer surplus is directly linked to the distribution of utilities used in the behavior models, guaranteeing perfect consistency between the socioeconomic benefits calculated and the revealed behavior of the consumers.
- In the framework of discrete choice utility models of multinomial logit or nested logit type, the calculation of surpluses with this method is simple (logsum differences, given as the results of the models).
- This method prohibits the contradictions raised previously, notably in the case of toll infrastructure projects where the normed mean benefit may be negative.

However, two difficulties should be taken into account:
- The level of the surpluses calculated depends on the formulation of the models, which does not lead to making effective comparisons between projects when they do not result from a single model (De Jong, et al., 2005).
- The result of the calculation depends heavily on the shape of the distribution curve, especially for high values. However, models are usually fitted for intermediate utility values. A major uncertainty may therefore exist for this distribution "tail", with a not inconsiderable impact on the surplus calculation. David Meunier (2014) also identified this risk and went as far as proposing to truncate inverse demand curves in the case of new projects with a high price for the consumer.

The following illustrations allow examining these points in greater depth.

3. Comparison of methods using an example of application

3.1. Definition of the case of application

The case of application is a given origin-destination relation between two points A and B, on which a traffic flow of 18 000 veh/day is observed. In the reference situation, the road has a capacity C with a speed limit of 90 kph. On option with the project, the road runs parallel with a dual carriageway with a capacity of 72 000 veh/day with a speed limit under fluid conditions of 130 kph.

The tests focused on a series of scenarios with variations of three variables: the length of the project (30km, 60 km or 110 km), the speed on the empty highway (130 kph, 110 kph, 90 kph) and the capacity of the parallel road (20 000 veh/h, 24 000 veh/h or 30 000 veh/h). The modification of the capacity of the parallel road with constant demand allows adjusting the level of congestion of the corridor considered.

The table below summarises the case in point used in the following analyses. The generalisation to all the tests performed by varying the length, speed and capacity is proposed afterwards.

A congestion model is applied (30 iterations), integrating the speed-flow curves for a highway and a trunk road to simulate the time-saving between the reference and the project more realistically.

	Reference option	Project option		
	road	road	highway	unit
Empty speed	90	90	130	kph
Trip time, road empty	80	73	42	min
distance	110	110	90	Km
Gasoline cost	6.2	6.2	5.1	€ tax inc.
Toll			12.6	€ tax inc.
Total monetary cost	6	6	18	€ tax inc.
Time saving		7	38	Min
Gain in cost (monetary)		-	- 11	€TTC

Table 1: hypotheses of cases of application

The speed-flow curves used are the following:
sat = q / (qmax *c)
critical sat = 1
heavy t = t0 * (1.1 - a*sat) / (1.1 - sat) for sat < critical sat
heavy t = t0 * (1.1 - a)*sat² / 0.1 for sat > critical sat
The values of a and c taken into account:

- Highway: a= 0.9 and c=1.1
- Alternative road: a=0.65 and c=1.2 (in the reference situation and the project situation).

Two models are applied to estimate the market share of the road / highway: an “Abraham” model and a time-cost model.

The “Abraham law”, also known as the Logarithmic Logit, was developed in the 1960s in France by the Roads Department. It is a version similar to the Probit model that postulates that generalised costs are distributed according to a normal law. It appears that the first formulation of the Probit model was due to Claude Abraham and Roger Coquand (1961) and that it was reformulated and rigorously analysed by Daniel Mac Fadden (1973) and Mosche Ben Akiva (1973) among others.

Abraham’s law is written as:

$$\frac{T_2}{T_1 + T_2} = \frac{1}{1 + \left(\frac{C_2}{C_1}\right)^k}$$

Where T_j is the traffic of itinerary j and C_j is the generalised cost of itinerary j and where

$$C_j = p_j + VDT \times t_j$$

With p being the price of the trip and t the journey time.

In the case of application, the parameters taken into account are: *k*=10, *VDT*=€18.7/h

The second type of model used here is the time-cost model, first formulated by Claude Abraham, Thierry Baumgart, Jean-Didier Blanchet (1969). In this type of model, the generalised cost of itinerary *j* for individual *i* takes the form:

$$C_j^i = p_j + t_j \times VDT^i$$

Where *p* is the price of the trip (toll + gasoline) and *t* the journey time.

In this model, the individual generalised costs depend only on time values and their distribution. It is generally accepted that the distribution of individual time values obeys a log normal law, as does income distribution (Bonnel, 2004).

The individual advantages or benefits are written as:

$$a^i = C_2^i - C_1^i = p_2 - p_1 + VDT^i \times (t_2 - t_1)$$

There is a time value, called changeover, beyond which the estimated benefit becomes positive:

$$VDT_b = \frac{(p_2 - p_1)}{(t_1 - t_2)}$$

Individuals who obtain a benefit from itinerary 2 in comparison to itinerary 1 (in the project situation) and who use the infrastructure, are individuals for whom the individual time value is higher than VDT_b.

In the case of application the value taken into account for the distribution of the time value is *VDT*=18.25, with a standard deviation of *ln(VDT)* of 0.48. These parameters are fitted to minimise the squared deviation of the route market shares (toll function) between Abraham’s law and the time-cost model.

The induced traffic is not integrated in the calculation of benefits in the following examples. The induced traffic is generally limited to about 10% of demand in the type of case studied when the level of the toll is low, and considerably less when the level of the toll is high. The benefits (semi-benefits) linked to the induced traffic will therefore clearly be of the second order and thus not modify the results. What is more, the uncertainties on the reality of the estimated induced traffic are very high.

3.2. Calculation methodology

The results given further on are obtained by comparing a calculation of the benefits with the classical method (method using the mean time values revealed by the model) and a calculation of the benefits with the so-called “distributed benefits” method that reutilises the distribution of individual benefits determined by the model used.

It is noteworthy that the calculation of the classical method raises the question of multiplying the time-saving by the mean value of the time values or by the median. We know that the central value of a log-normal distribution can be written by two parameters: the mean value and the median value of the variable. In classical distributions of the time value, the median is approximately equal to 70% of the mean. Regarding this point, official French reports (Boiteux, 1994 and 2001) are ambiguous and do not indicate, in the case of time-cost models, whether the recommended value is the mean value or the median value. Here, we use the mean value which is more consistent with the calculation of the distributed benefits, since for a zero toll, the distributed benefits method amounts to calculating the integral of the distribution law and the mean value.

Regarding the time-cost method, the "distributed benefits" method corresponds to a simple calculation to determine the mean time value for the users of a highway on the one hand and of a road on the other hand. The time-saving is multiplied by this mean time value by the user category.

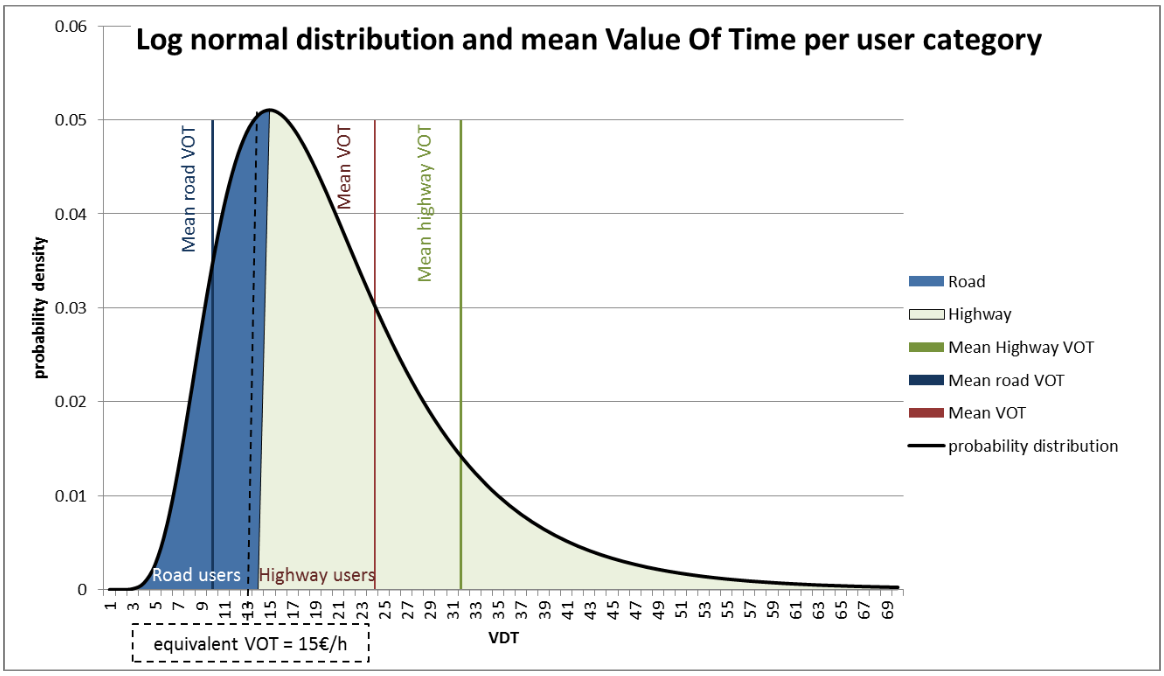


Figure 4: Illustration of the time value differentiated between the users of a road and those of a highway.

The curve above shows that the mean time value is strongly affected by high time values of the tail of the log-normal distribution.

Regarding the logarithmic logit model (Abraham's law), the calculation of the highway benefit distribution in comparison to the road of the reference option cannot be formulated easily. Indeed, the distribution law permits determining a distribution of the benefits of the highway option of the project in comparison to the road option of the project. However, the socioeconomic calculation requires calculating the benefits of the highway option of the project in comparison to the road in the reference option. The two methods tested gave very similar results, illustrated in the two graphs of figure 5.

The first method adopted consists in shifting the distribution of the benefits of the highway/road$_{project}$ from $B=C1-C1_{ref}$. The highway users correspond to the integral of the blue curve for $x>0$. If we consider that the road option of the project presents *a* benefit *B* in comparison to the reference road option (non-distributed since it is the same infrastructure, the same cost but different journey times), and that the highway presents an advantage x in comparison to the road option of the project, then the benefit of the highway in comparison to the road in the reference option can take the form $B+x$ for $x>0$.

The second method consists in calculating a dummy distribution competition between the reference road option and the highway project option (red curve in the right-hand graph). X_0 is determined so that the integral of the blue curve for $x>0$ is equal to the integral of the red curve for $x>X_0$. The advantage for the users of the highway project in comparison to the reference road is therefore the weighted mean of the benefits on the green curve. The two methods give very similar results.

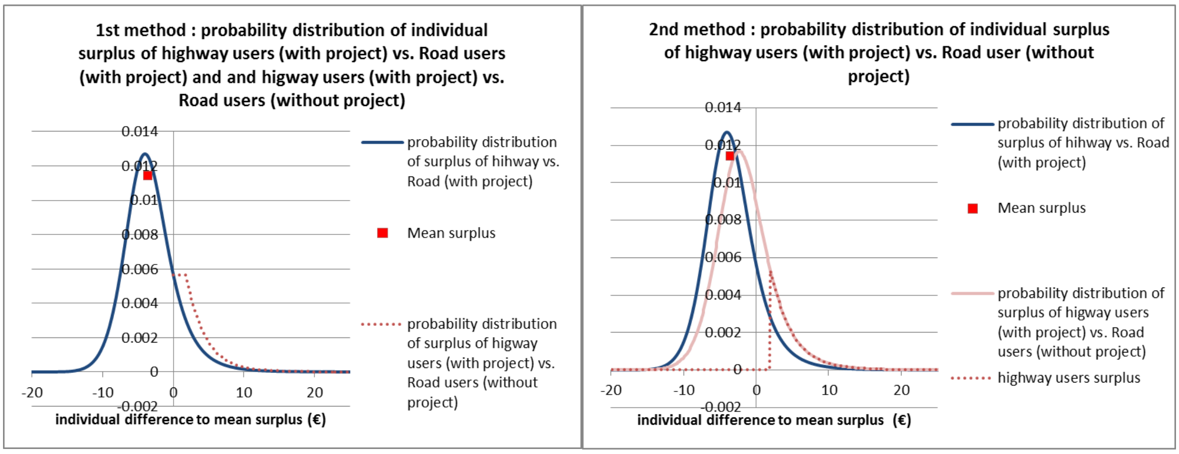


Figure 5: Probability distribution of individual benefits of the highway versus the road.

The benefits of the users of the road option of the project can be distributed (by considering that the consumers remaining on the road have a lower time value than those having chosen the highway; the mean time value applied can be calculated for the sub-population of the road users) or not distributed (taking account of the mean time value for the whole population).

4. Analysis of the results

4.1 Individual benefits

The individual benefits of the highway users calculated with the "distributed benefits" method are systematically higher than or equal to the benefits calculated with the classical method. Indeed, the users taking the highway are those whose time values are the highest. By calculating a weighted mean of the benefits for the highway users, we obtain a higher value than that obtained when taking the mean time value of the whole population.

It is noteworthy that the individual benefits are both a function of the time savings obtained by the highway and of the costs, including the toll costs. In particular, we observe that, in this example, for a toll > €0.2km, the time saving obtained by the highway in comparison to the reference is offset by additional costs (toll) for a time value of €18.7/h. This therefore implies a negative benefit for the highway users with a classical evaluation, despite the fact that they take the highway and therefore obtain a benefit (it should also be noted that the road on option in the project is systematically more interesting than the road in the reference option).

For a zero-toll value, nearly all the traffic is on the highway (since the capacity of the highway permits accommodating all the demand without any significant deterioration of traffic conditions). The mean value of the time value of the highway users is equal to the mean value for the entire population. Thus, for a zero-toll, the classical method (benefits calculated with the mean time value) gives the same result as the distributed benefits method.

The function that links the individual benefit of the road users to the toll is strictly diminishing in the classical method (the higher the highway toll, the more traffic on the road and thus less time is saved). In the case of the distributed benefits, the individual benefit of the road users starts increasing with the level of the toll before decreasing. This paradox can be explained by the fact that for a very low toll the only users left on the road are those with a very low time value, resulting in time savings of low monetary value. The more the toll increases the more users remain on the road and have increasing time values. On the contrary, the bottlenecks on the road augment and the mechanism represented by the flow-speed curve leads to a reduction in time-saving provided by the traffic opting for the highway.

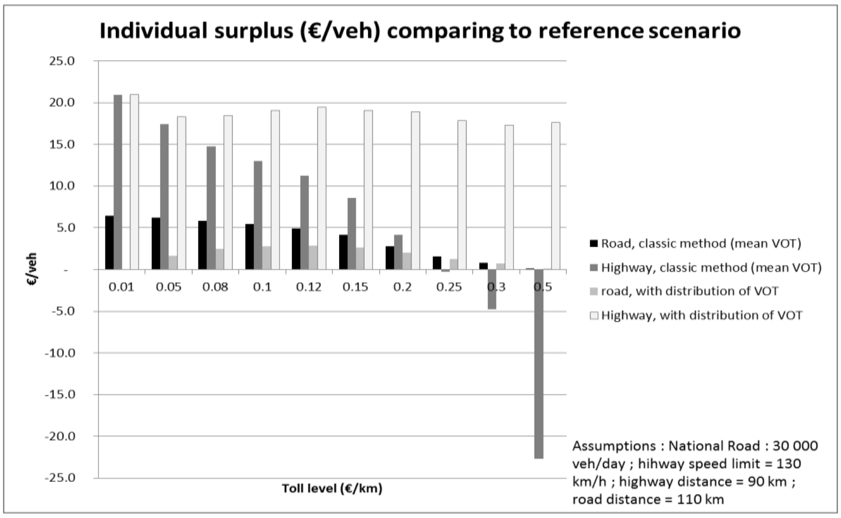
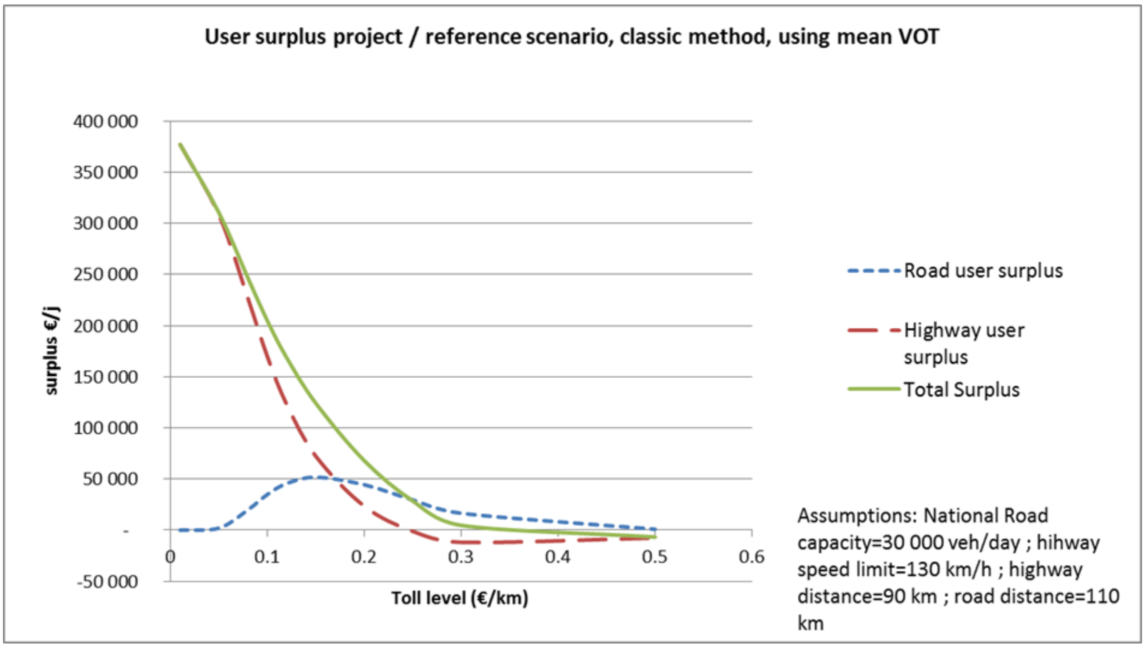


Figure 6: Unit benefits as a function of highway toll level, time-cost model.

The shape of the log-normal distribution shows that there is a maximum individual benefit for the road users of about €0.12/km for the highway toll. Beyond this, the increase in the time value of the road users no longer offsets the loss in time-saving linked to heavier traffic on the road.

4.2 Global benefits

In the classical method, the benefits for the highway users become negative above €0.2/km and the global benefits are almost zero as from €0.3/km, whereas with the distributed benefits method, the global benefits remain significantly positive. This difference appears clearly on the two graphs of figure 7 which illustrate the surplus as a function of the toll according to whether the calculation is based on a mean time value (upper graph) or a distributed time value (lower graph).



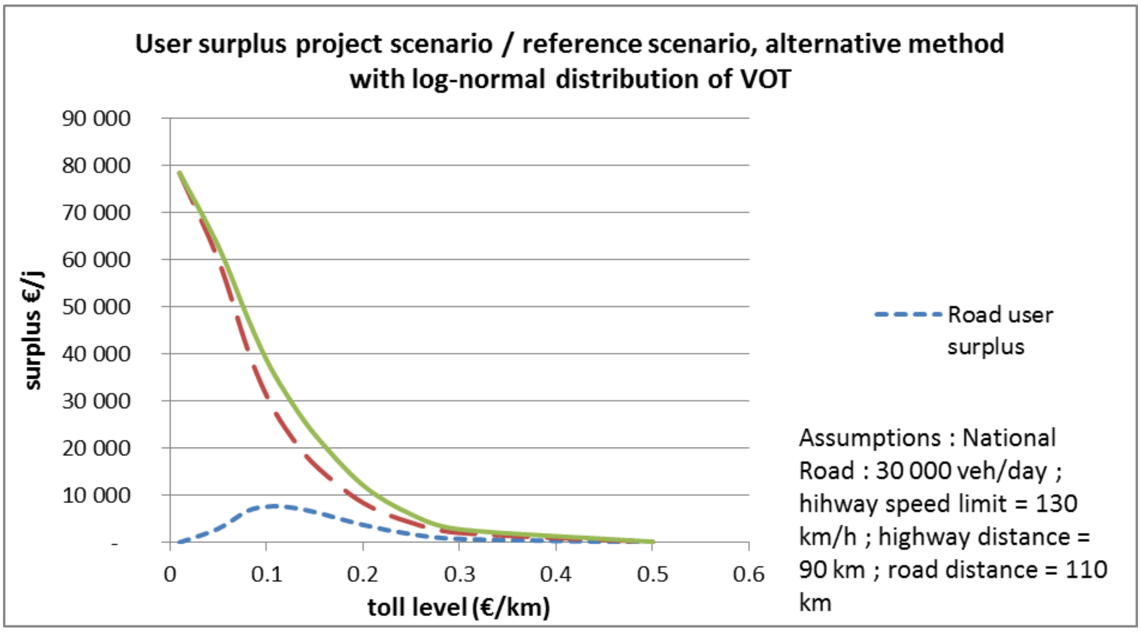


Figure 7: The variations of the surplus as a function of tolls according to the calculation method (classical method or distributed method, time-cost model).

In addition to these effects observed on the high toll values, this example shows that the benefits evaluated with the distributed benefits method are systematically higher than the benefits resulting from the classical method, whatever the level of the toll, as confirmed on Figure 8. The variances highlighted between the two methods are considerable and vary greatly depending on the level of the toll price taken into account. For a toll of €0.12/km, which corresponds to a level close to that practiced on recent French highways, the user benefits are nearly 40% higher in the "distributed benefits" method versus the classical method!

Obviously, this result may be of great importance, both in ranking the projects, especially when comparing different modes of transport, and in determining pricing policies.

As mentioned in the introduction, the consumer surplus generally represents half the Net Present Value of a highway project (Chevasson, 2007). If we consider that the fundamental criterion of ranking projects is value for money, corresponding to the Net Present Value and, in money, to the amount of public expenditure, then an increase of 40% of consumer surplus increases the NPV/subsidy ratio by more than 20%, thus substantially improving the project's position in an intermodal ranking.

The other impact of the results presented in Figure 8 on transport policy concerns optimal pricing problems. It is clear that for tolls considered high in France, i.e. more than €0.12/km, the loss of consumer surplus is greatly underestimated by the distributed benefits method. If we add this to the analyses that can be performed of an optimal toll that takes into account the public funding scarcity coefficient (Bonnafous, 2016), then this result justifies relatively high tolls.

4.3. Modification of the results as a function of the model used

The results presented for the time-cost model are also valid for the logit logarithmic model, but with much smaller variances between the "classical" model and the "distributed" model. As long as the toll is low and the market share of the highway is large, there is relative little variance between the classical method and the distributed benefits method.

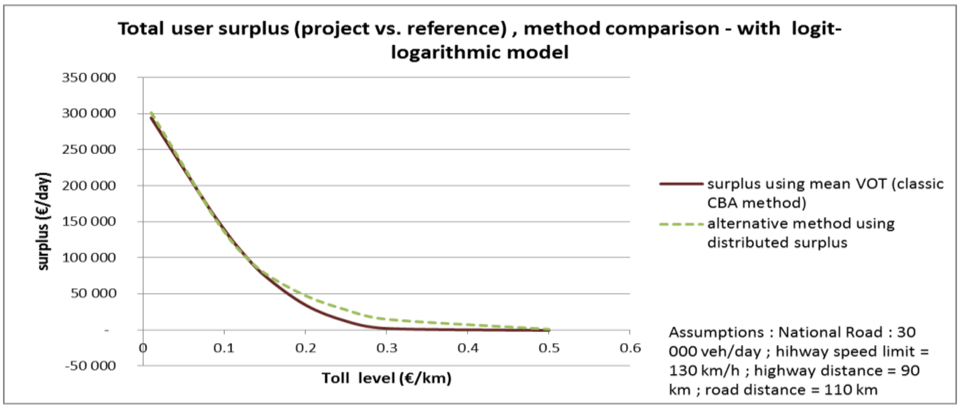


Figure 8: Variation of consumer surplus, comparison of calculation methods.

The weighted sum of the benefits on the highway is almost the same as the product of the mean benefit resulting from the highway traffic. For values above €0.2/km, the distributed benefits method leads to greater consistency with the economic logic of the consumers: as long as the consumers take the highway, they obtain a non-zero benefit. The variance between the classical method and the distributed method is in the region of 40% for €0.2/km.

It is noteworthy that forecasts are generally determined in France for toll prices that are generally lower than €0.2/km. On the basis of these magnitudes, the two types of calculation give market shares between the two itineraries as a function of very similar tolls, as shown in Figure 9 according to whether Abraham's or the Cost-Time model is used. Using one or the other models therefore does not have a major impact on traffic forecasts or receipts. This is not the case for calculations of surpluses which obviously depend on consent to pay, and thus demand, high toll rates.

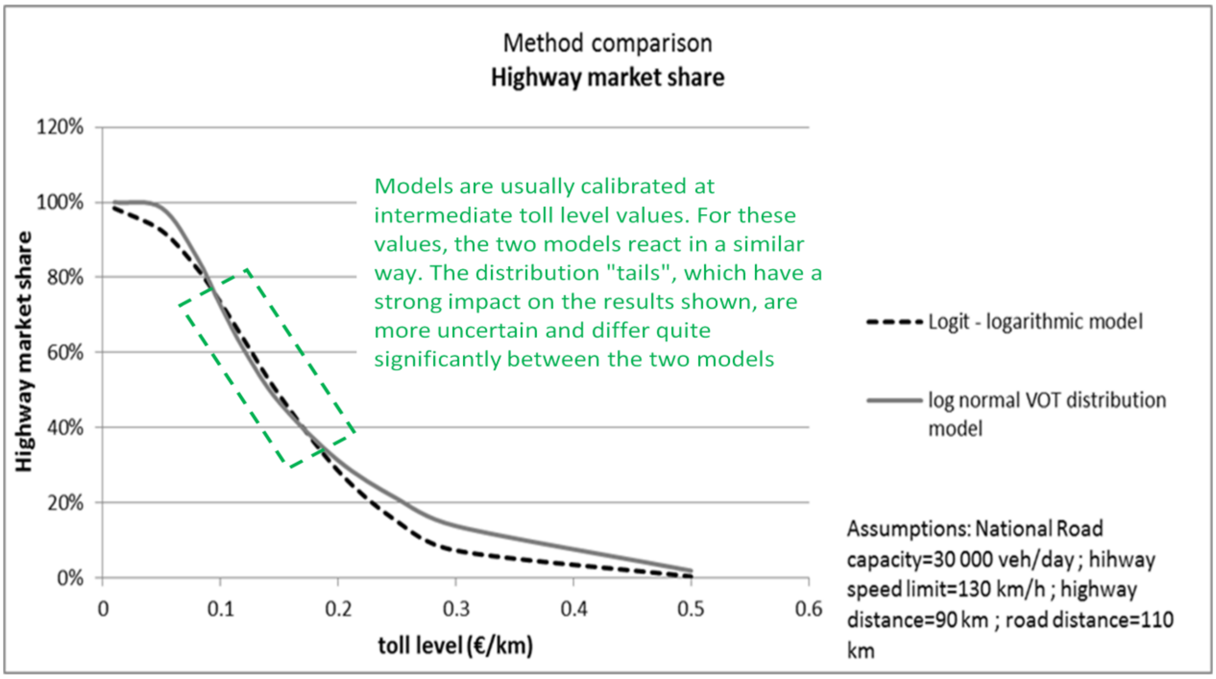


Figure 9: Comparison of highway market share according to the model used.

The tests carried out by varying the parameters of the case study also show that for a shorter project (30 km versus 110 km in the first example – the length of the road is also shortened to 30 km), the two laws superpose each other better (cf. Figure 10). It should be noted that when using "Abraham"s law", it is applied to all the traffic, whatever the costs (or the length of trips), meaning that the estimated benefits occur as a function of relative gains. Therefore the length of the project may have an impact on the gains of itineraries, modifying the market share curve as a function of the toll. In this example, the distributed benefits method applied to a logarithmic logit model has a greater impact than in the previous example: at €0.15/km, the variance reached nearly 80%, as shown in Figure 10.

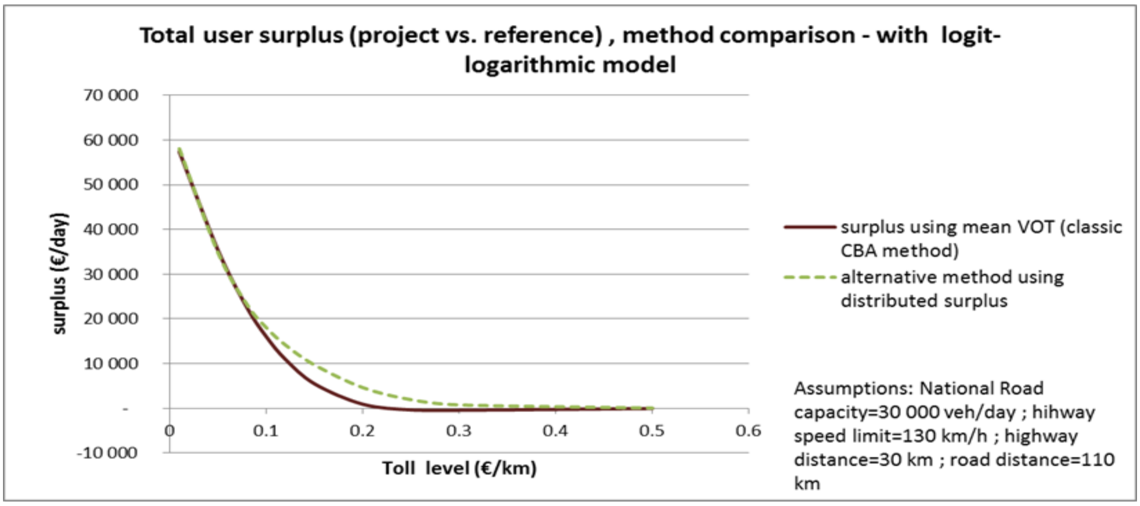


Figure 10: Variation of consumer surplus, comparison of methods (short project).

In the case of the cost-time model, the global benefits are systematically higher with the distributed method than with the classical method in the 9 cases studied. The difference between the distributed and classical methods narrows however in the case of heavy congestion on the parallel road.

As we saw, in the case of the "Abraham" model, the distributed and classical methods were closer. For certain examples (particular in the case of heavier congestion), even in the case of low toll values, the distributed method gave globally lower benefits than the classical method. Thus, the underestimation of the classical method was not systematic with this model.

Thus, we conclude that there is considerable dispersion of the benefit values calculated according to the type of model used, but what is important is that the distributed benefits approach is indisputably closer to the values revealed by behaviors and therefore to a certain reality that does not mask the diversity of behaviors.

5. Conclusion

Whatever the behavior law used (cost-time model or logarithmic logit model), for the classical configurations of the project tested (road-highway competition as a function of different characteristics: distance, speed and level of congestion), the classical calculation method generally underestimated the consumer benefit in comparison to the "distributed" method which made direct use of the statistical distribution of time values. This underestimation was systematic for the time-cost model, though for the Abraham model it depended on the configuration (distance, congestion).

How can the theoretical calculation of surpluses corresponding to the discrete choice models, and the "reference" values of the mean benefits be reconciled? Despite the fact that the method using the distribution of benefits resulting from the models is more consistent with economic rationale, the results greatly depend on the model used. Although the literature since the 1970s has established the pertinence of using utilities derived from discrete choice models to estimate consumer surpluses (Williams 1977, Daly & Zachary 1978, Small & Rosen 1981), only a few cases of application have been reported. This can be explained by the strong dependence of the results on the way the model is formulated (a point we have also underlined here), making any comparison between the project evaluated with different models difficult if not impossible. The utilisation of a sole model (a national or regional model used to test different projects) would make more systematic use of a "distributed" calculation possible. There are currently many different models in France but they are rarely shared by the actors. This configuration severely restricts the pertinence of methods of calculating "distributed" benefits. However, within an entity equipped with a single model used to test different projects (the State and territorial authorities equipped with a proven multimodal model, the SNCF (French railway network) has a national model, etc.), it appears pertinent to consider performing the calculation twice, i.e. using the distributed and classical methods.

Thus, at present there is probably no other solution in many countries except to perform a socioeconomic calculation based on data recommended by official instructions. However, we think that we have provided several arguments in favour of systematically carrying out a calculation of the distributed advantages based on the values revealed by behaviours such as they are estimated by discrete choice models. This recommendation is shared by Roquigny (2014). It also appears important to indicate the reducing and thus cautious nature of the mode of calculation recommended for projects with a high cost of utilisation. The full calculation could at least be performed, notably by actors equipped with a single model used to evaluate several projects, to obtain a safety margin equivalent to that obtained with the classical method.

Since the risks of underestimation were evaluated satisfactorily, what is important is to take these risks into account to determine both the order of carrying out competing projects and to determine optimal tolls.

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