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OPEN ISSUES IN THE PRACTICE OF COST BENEFIT ANALYSIS OF TRANSPORT PROJECTS

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ABSTRACT

Cost benefit analysis is the commonly used tool to evaluate transport investments. Despite its diffusion, both the technicalities and the purpose of the analysis differ among countries. This paper focuses on some common issues and lacks still present in the evaluation of transport projects, in the light of the most recent contributions in the literature. We try to clarify two open issues: the treatment of the mode shifting component of induced traffic, the treatment of lost fuel taxes due to mode shift and of generated fare revenues and the evaluation of impacts during construction and maintenance. Moreover the paper describes and discuss the use of some advanced techniques: the use of conversion factors to assess the shadow value for labour costs and public funds, the treatment of wider economic effects, the use of distributive analysis and the use of risk analysis.

Keywords: cost benefit analysis, transport project, consumer surplus,

INTRODUCTION

Cost benefit analysis (CBA) is the commonly used tool to evaluate transport investments. Though being a commonly and relatively established tool, CBA methodologies still differ significantly in different countries, even inside the EU. Olsson, Økland and Halvorsen (2012) carried out cost-benefit analyses of the same project (the upgrade of a 22 km suburban railway, linking Oslo to the town of Ski) using the methodologies of Norway, Sweden, Denmark, the UK, France, Germany and Switzerland. Results in terms of Net Present Value (NPV) range from a negative -889.3 M€ with the Danish methodology to a positive 1,626.0 M€ with the British methodology. To do that, the authors referred to the used values (appraisal period, discount rate, values for travel time savings, etc.), but not on the way some costs and benefits are assessed. Even considering that the results of CBAs are differently used in each country appraisal process and at different stages (Beria et al., 2012), the differences are still striking.

Our paper starts from the consideration that many differences and incoherencies seem to exist worldwide in transport appraisals, even at the methodological level. This has been already pointed out, for example, by Mackie and Preston (1998), analysing twenty-one sources of error and bias in transport projects, related to objectives, definitions, data, models and evaluation conventions. In 2011, an international round table was promoted by the International Transport Forum at OECD (2011) to discuss how to improve the practice of transport project appraisal, both in terms of its role and in its technicalities.

However, in our opinion, some issues still need to be faced more clearly. This paper has the main purpose to give practical indications on some key aspects of CBA, taking care of coherence and correctness from the theoretical point of view. We consider in the next sections the following issues, that together do not cover all topics of CBA, but represents the less consolidated ones:

- the treatment of the mode shifting component of induced traffic;
- the treatment of lost fuel taxes due to mode shift;
- the impacts during the construction stage (external costs and effects on existing traffic);
- the use of conversion factors to assess the shadow value for labour costs and public funds;
- the treatment of wider economic effects;
- the use of distributive analysis;
- the use of risk analysis.

In the first part of the paper we will discuss the issues related to the first three topics, which refer to the “standard” CBA, which includes the most consolidated positive and negative impacts of transport projects and the technicalities used to manage them: investment and management costs, surplus variation, external costs, basic indicators, sensitivity analysis. The first two of them still seem to be treated in completely different – and, necessarily, sometimes flawed – ways in practice, while the third seem to be seldom considered.

In the second part of the paper we will instead refer to the other four topics, not totally consolidated in practice (but often well understood in the scientific literature), but that can, in our opinion, extend the analytical and interpretative scope of CBA.

OPEN ISSUES FOR STANDARD COST BENEFIT ANALYSIS

We start analysing the issues that still emerge in the commonly used “standard” cost benefit analysis.

The most problematic one is that of surplus calculation for induced users. In particular, while generated demand is quite universally treated with the so called “rule of half”, different approaches are used to deal with the surplus of the demand shifted from other transport modes.

The treatment of the mode shifting component of induced traffic

The variation in user (or consumer) surplus is a key point in transport project and it represents one of the components of social surplus (together with, according to different classifications, producers' surplus, government's or taxpayer's surplus and the surplus of rest of society).¹ The calculation of the surplus of users shifted from other modes might appear as trivial, but still the assessment of such benefits is unclear if looking at many official guidelines. This aspect is particularly relevant for public transport and rail projects appraisals, where mode shift from private road transport is usually a main objective.

When evaluating a transport project, we need to compare transport costs before and after the project for mode shifting users (for example, those leaving the car after an improvement in rail travel times), as we do for existing users, that already travel on the transport mode that will be affected by the considered project. In some practical cases, the way this evaluation was carried out raised concerns, as a commonly used approach is simply to evaluate the users' benefit as the difference between the unit operating costs of the two modes.²

In this section we want to show that this last approach overestimates the user's benefits and is wrong for at least two reasons:

- the users' benefits associated to a trip must be necessarily calculated referring to their generalised cost and not to the operating costs only;
- the presence of different "unobserved parts" associated by users to different transport modes, makes even the comparison among typical generalised costs (monetary costs plus generalised time; see below) of different modes not recommendable.

Let's consider an example. Assume that two links initially exist between A and B, being one a road and the other an old rail line. Consider a project that builds a new rail line, allowing a time saving for travellers from A to B. As a consequence, existing users will remain on the rail mode (assuming that other costs remain unchanged), enjoying the time saving. In addition, some new users will start travelling (generated demand). Some other users will likely abandon their private car in favour of improved train services (shifted demand). When shifting from the private car to the train, they will likely experience a significant reduction in operating costs (from car operating costs to rail fare), but it will also likely be offset in rail transport by many other factors (less time and space flexibility, access time to stations, waiting times, possible less comfort, etc.) that – together with the journey time – make up the so called "generalised cost" (GC; or, more precisely, the "generalised price") of transport: it represents the cost that users associate to the trip and upon which they make their transport choice.

In general terms, the project will reduce the GC for the rail mode, by lowering the journey time:

$$GC_{1,rail} > GC_{2,rail},$$

$GC_{1,rail}$ and $GC_{2,rail}$ being respectively the generalised cost of using the rail before and after the investment. The unit benefit for former rail users will then be: $GC_{1,rail} - GC_{2,rail}$.

¹ In the real world, consumers' surplus and social surplus seldom coincide for various reasons. One is because of the presence of (both negative and positive) externalities and taxes that make perceived costs (prices) differ from resource costs. Those aspects obviously have to be taken into account to estimate to total amount of costs and benefits (see paragraph 0).

² An intense debate on this issue arose in Italy after the presentation of the results of a cost-benefit analysis made by the proposers of the Turin-Lyon high speed rail project (Maffii, 2012).

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The users that, after the investment, abandon the private car in favour of rail transport are now better off ($GC_{car} > GC_{2,rail}$, GC_{car} being the generalised cost of using the car), but surely attributed a lower (or equal) generalised cost to the private car than to the rail for their trip before the investment ($GC_{1,rail} > GC_{car}$), otherwise they should already use rail before the investment.

$$GC_{1,rail} > GC_{car} \geq GC_{2,rail} \text{ for shifted users.}$$

As they already had chosen their best option between $GC_{1,rail}$ and GC_{car} , their benefit will be the difference between their former GC and the new one:

$$GC_{car} - GC_{2,rail}$$

It should be clear that their benefit is, by definition, lower than that of existing rail users. The “last” shifter, namely the marginal user, has instead a benefit equal to zero.

Thus, as a first rule, when comparing perceived generalised costs of different transport modes, we must verify:

- that the generalised cost of the transport mode the user will shift to, used to be higher (without the project) than the one of the mode the user abandons; ,
- that it is now expected to be lower that, with the project.

If this is not the case, the user will *not* shift mode or the generalised costs we are considering are not explaining enough of its behaviour and thus are inappropriate to make an evaluation. However, and this is the second point, comparing costs for all the mode shifting users before and after the project is difficult or even practically impossible most of the times (Mohring, 1993). In other words, both $GC_{1,rail}$ and GC_{car} are unknown in all their components. This is because the typical estimations of generalised costs that appraisers use, even when well constructed (already a very difficult task), usually miss the unobserved parts of the disutility of travel, usually controlled for via mode specific constants in transport modelling (see for example DfT, 2012: TAG 3.10). While the existence of this unobserved parts usually does not represent a significant problem when evaluating benefits for one single mode (we can usually assume the unobserved parts to remain constant before and after the project and thus offset each other), the values of the unobserved parts may vary significantly among modes, thus compromising the correct assessment.

For this reason, many sources (Abelson and Hensher (2001), Prud’Homme (2007), Maffii et al. (2012), TEC (2012)) suggest that the only way to correctly evaluate the benefits for the mode shifting component of induced traffic is to refer only to the mode where the benefits occur (Mohring, 1993; Kidokoro, 2004) and to attribute the benefits to the whole induced component by studying the form the demand function (again for the final mode, that is where the benefits occur). In other words, as it is unknown the *absolute value* of generalised costs of *all users* for *all modes*, before and after the new investment is made, we need a tool based on the only information available: the variation of generalised cost for the invested mode and for the only segment of all trips involved in the investment.³ If unit benefits are small when compared to the generalised cost, and one can thus assume demand function to be linear, the tool is the well known “rule of half” (Abelson and Hensher, 2001; Kidokoro, 2004; DfT, 2012: TAG Unit 3.5.3).

³ For example, we do not need to know the costs of all trips passing through a new tunnel, but only the variation of the cost of the previous road segment substituted by the new tunnel.

The demand curve (the blue line in Figure 1) represents the relation between perceived costs (in the case of transport, the generalised cost) and the consumed quantity (in the case of transport, trips made).⁴ As said, a new project is expected to lower costs of the transport mode that will benefit from the investment (for example from GC_1 to GC_2): this reduction will increase trips from Q_1 to Q_2 . In order to estimate the consumers' surplus it is not necessary to distinguish trips which are generated from those that represent a change in route, mode or time of travel. The linear approximation of the demand curve (an acceptable approximation if the variation in generalised costs is relatively small, see Nellthorp and Hyman; 2001) allows to estimate the change in consumers' surplus as follows:

$$\Delta S_{\text{consumers}} = \frac{1}{2} \times (GC_1 - GC_2) \times (Q_1 + Q_2)$$

This is the "rule of half" and allows to consider only the known (because measurable) variations of generalised costs.⁵ It is also coherent with the conditions explained above. In particular, the benefit of mode shifting users cannot be higher than unit benefits than existing users ($GC_1 - GC_2$). This is because the new user with the highest benefit is the former marginal user (at Q_1).

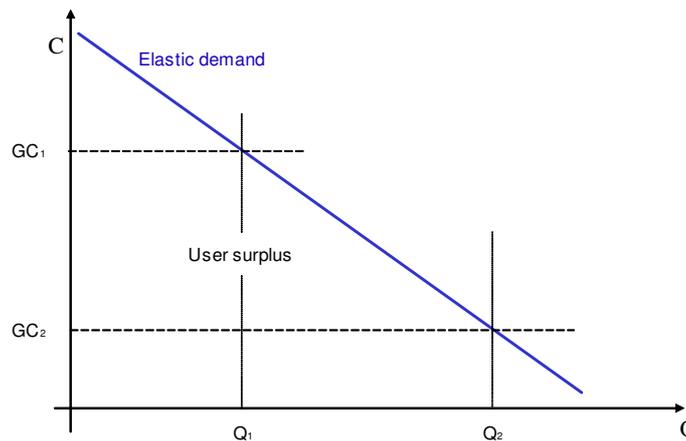


Figure 1 - Standard representation of the consumers' surplus evaluation through the so called "rule of half".

When a transport model is available, the rule of half is applied to each origin-destination pair, obtaining a more precise estimate of benefits, instead of using the aggregate measures of total demand using the link and average generalised cost variation (World Bank, 2005).

This issue was explicitly raised in the past by Prud'Homme (2007) when commenting the RailPAG manual (EC-EIB, 2005). However, many guidelines still seem to be unclear about the treatment of the mode shifting component of induced traffic when evaluating user's benefits. Other guidelines instead face the issue explicitly enough, we provide here some non exhaustive examples:

- the European guidelines (DG Regio, 2008): *"when the diversion is between different modes, as in the railway case studies, the benefits are estimated on the basis of the change in surplus of the two markets, road and rail. It is important to note that the relevant prior generalised cost against which the change in travel costs is assessed,*

⁴ Different curves could be estimated also for different time of the day.

⁵ The information contained in the in the "consumed quantity – perceived generalised cost" after the project already surrogates what happened in the substitute market.

- are those for the mode to which users have switched, not the costs associated with the mode used in the BAU scenario;”
- the Irish guidelines (DoT, 2009): “Where there are investments that induce mode changes, the benefits are calculated by applying the above formula (consumer’s surplus through the rule of half, ed.) to each mode separately⁶ and summing the results. The benefits are thus not based on a comparison between the costs of the two modes;”
 - the British guidelines (DfT, 2012: TAG Unit 3.5.3): “The main substitutes and complements for travel from A to B are travel from A to other destinations, by other modes, using other routes and so on. Notwithstanding this, provided that consistency can be achieved between the pattern of travel demand and the outturn costs - and this is key for the evaluation - the rule of a half formula can be extended to cover network appraisal with many modes and origin/destination pairs;”
 - the Spanish guidelines (CEDEX, 2011): “The increase in travel ($q_1 - q_0$) can be generated or diverted from other modes of transport. Its treatment is identical. What happens in the secondary market supplying the diverted demand is another issue. Users of these markets might be affected by the changes in their equilibria as a result of the reduction in travel in these markets. The specific measurement of the intermodal effect is identical to the measurement of indirect effects in any other market”.
 - the guidelines of the World Bank (2005) include users who change their mode among “induced traffic” and suggest that “in the majority of situations the calculation of the user benefit associated with induced traffic is relatively straight forward and utilises the Rule of the Half (RoH) methodology”.

Moreover, one of the most extensive evaluations of a very big infrastructure carried out in recent years, the High Speed 2 in the UK, clearly makes use of the right approach (HS2, 2011): “For HS2 users who have switched from other modes (for example if they took the car or used air travel for a particular journey before HS2) and those who would not have travelled at all before HS2, then the valuation of benefits resulting from HS2 is more complex. For these “new” rail travellers, their motivation for switching to HS2 will vary. There will be some new users (whether switching modes or travelling more frequently) who would have made the switch to HS2 even if the time saving benefit had been very small e.g. 1 minute; these users then value the additional time saving (29 minutes). Other new users would not have made the switch if the time saving had been anything less than 30 minutes; if the time saving had only been 29 minutes, then they would not have taken HS2; these people only gain a marginal benefit from using HS2. We assume that the average benefit is the mid-point of the range, so in this example it would be 15 minutes. For these “new” rail travellers, the value of the benefit is therefore half of their full value.”

⁶ That is, costs must not be compared among transport modes, but just inside them – before and after the investment.

The treatment of lost fuel taxes due to mode shift and of generated fare revenues

This issue is somehow related to the one in the former section: as transport modes are taxed differently, there can be a significant impact in governmental tax revenues when users change mode. The conventional CBA approach suggests that taxes can be ignored, because they simply represent a transfer from the consumers' to the government's surplus, and those two components simply cancel out and do not represent consumed resources. The same applies to fare revenues, those being a transfer from the consumers' to the producer's surplus.⁷ This is clearly right.

However, when evaluating the consumer's surplus of mode shifting users through the conventional "rule of half", which is in our opinion – as seen in the former section – the only viable option for assessing induced users' surplus, we compare their perceived (or private) generalised costs and not the associated social ones (because, as seen in the former section, we can not). This way, considering for example users shifting from private car to rail transport, we are already accounting the fuel taxes they used to pay when they were car users and the fares they now pay as new rail users, which are not consumed resources but simply transfers. So, if we do not reflect those aspects by considering them in the government surplus (as a reduction in fuel taxes) and in the producer's surplus (as an increase in fare revenues), we are not balancing the transfers and thus introducing a mistake in the analysis.⁸

Figure 2 gives a fictitious qualitative example of the possible difference in the unit mode shift benefits if assessed as a difference in perceived costs or in social costs. The difference between the two columns of the left chart (perceived costs) is what we can calculate with the "rule of half", while the one between the two columns on the right is what we want to evaluate in a CBA, that is the variation in social costs of consumed resources.

⁷ We do not take account here of any possible variations in external social costs associated to transport modes or of possible increases in public transport services (and related operating costs) supply needed because of induced demand. If those elements occur (as it is often the case in transport projects) those elements should be accounted separately (as variation in government's surplus for external costs and in producer's surplus for new services operating costs).

⁸ It must be noticed that externalities must also be corrected, for the opposite reason, because not included in the users' surplus as calculated with perceived costs. Externalities are consumed resources, but are not perceived by the users. Taxes and revenues are not consumed resources, but are perceived by the users, so the evaluation of users' surplus made using the rule of half improperly considers them and - unless corrected - would introduce a mistake.

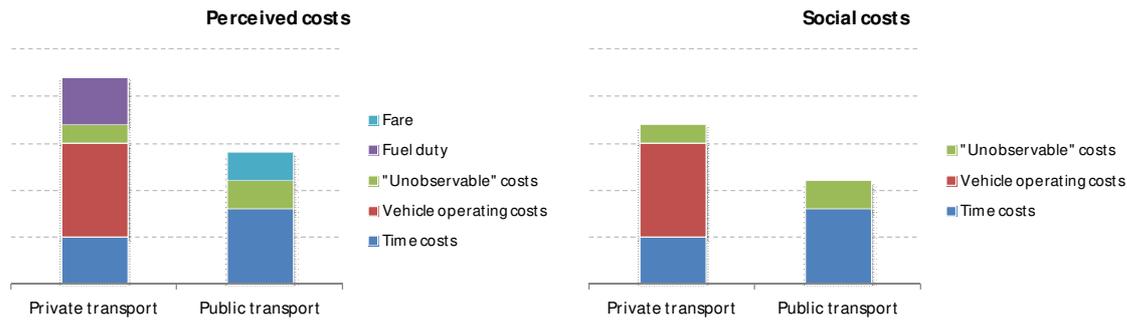


Figure 2 – Difference in comparing among perceived costs (on the left) and among social costs (on the right).

So, when using the “rule of half” to evaluate the consumers’ surplus (Figure 2, left), we need to correct it with the difference in taxes and in revenues associated with new demand (being it generated or shifted), whose estimation is possible and easy.⁹

$$\Delta S = \Delta S_{\text{consumers}} + \Delta \text{Taxes} + \Delta \text{Revenues}$$

Mackie (OECD, 2011) clearly explains this issue and the British debate about it, while the World Bank (2005) confirms this approach: “*User benefits/disbenefits associated with money costs (e.g. road tolls and fares), when calculated under the RoH and variable demand, do not net out with changes in the fare revenue element of the producer surplus calculation (i.e. they are not transfer payments)*”.

Impacts during construction and maintenance

Impacts during construction and maintenance formally do not represent a specific voice of the evaluation and its treatment does not pose particular methodological concerns or difficulties. However they are often neglected in appraisals because of the difficulties in getting information on the extent of impacts. A comprehensive list of those impacts in urban environments can be found in Gilchrist and Allouche (2005), however we can summarise them in the following categories:

⁹ An occasion for a discussion about such issue raised for example during the consultation process that preceded the refresh of the British appraisal methodology (one of the oldest and developed, now known as the NATA – New Approach to Transport Appraisal). Respondents to the consultation saw indirect taxation as being a transfer between users and government - this raised questions about whether indirect taxation ought to be appraised at all. The department responded to those concerns supporting the used approach using the same arguments we used above. Page 32: “*The NATA approach is to value impacts on market prices. To adjust between the two units of account, NATA employs an indirect tax factor, proposed in DoT (1977). This process allows any impact to be added to another. The use of market values means that even where indirect taxes are a transfer between parties, one gaining and one losing, we take a snapshot of the transaction after this has occurred. That means that analysis of monetised impacts will record that the Exchequer has benefited or lost and that the payments made by users are inclusive of any indirect taxes. A key issue to note is that any change in the overall payment of indirect taxes due to a proposal results from a number of transactions which ought to net out in overall impact. Any tax paid to Government has a counter-party – usually the transport user – who has made the payment. So, when a proposal widening a road is appraised, any increased traffic will result in indirect tax revenues to Government. However, transport users will see a commensurate negative impact as their payments of fuel costs will include this tax.*” (Page 32).

- *Impacts on traffic and economic activities*: disruption of existing roads and services (including parking space), because of the road space occupied by the building site and consequent costs in terms of congestion, higher travel times and longer paths;
- *Impacts on the environment*: external social costs of the environmental impact of the construction activities and materials production (in terms of air pollution, noise, climate change, water pollution, etc.) and external social costs of trucks used in the construction;
- In some cases, there might be also *impacts on safety*, as building site might temporarily reduce safety standards and cause more accidents on existing roads.

These issues are usually more significant in urban contexts, where urban space is scarce and the social costs are higher due to more people being affected.

With respect to road disruptions and safety impacts, one should assess them by using the same model used to predict the overall traffic effects of the scheme (as suggested, for example, in the British guidance; DfT, 2012: TAG Unit 3.5.2). Unfortunately the re-design of roads around construction sites is often done in the very last stages before construction actually starts, so it is difficult to correctly model them in the appraisal stage.¹⁰ Moreover, it might be that a more detailed model is needed with respect to the one used to make traffic forecasts for the considered project.

With respect to environmental impacts of the construction activities, there are evidences on the life-cycle GHG emissions of some infrastructures in the transport economics literature (see for example Åkerman, 2011; Network Rail, 2009; Westin and Kågeson, 2012). However, to our knowledge, there are only few sources suggesting unit external costs values of other emissions that could be applied parametrically. Nothing is said in consulted guidelines.

ADVANCED TOOLS FOR COST BENEFIT ANALYSIS

How to deal with advanced CBA tools

In this section we will present some “advanced” tools that can be introduced in a CBA. With these tools we can complement CBA basic results, which basically account for the users, producers and external net benefits and costs.

However, it is widely recognised that these direct and indirect effects do not totally catch all aspects that the decision-maker wants or should take into account when assessing a public investment. Leaving apart clearly qualitative aspects (like landscape, townscape, heritage of historic resources, biodiversity, etc.), these further aspects can be grouped into three types:

- a. the macroeconomic effects of an investment, in addition to the micro ones;
- b. the distributive aspects;
- c. the management of uncertainty.

We will discuss in the following each of them. However, as these aspects are still less formalised and could be manipulated by decision-makers, our suggestion is to produce separately the results of the CBA: one related to the “standard” issues and one or more extra scenarios which take into account separately (Table 1) the effects discussed in the following.

¹⁰ Simply closing the links and nodes affected by building sites in the transport model without introducing the reorganization of other roads would usually significantly overestimate impacts.

In this way the methodological rigour of the standard can be preserved and the further, useful, information related to the macro, distributive and uncertainty aspects are not lost.

Standard NPV	“Advanced” NPVs
Users surplus	Including macro-economic effects
Externalities	Including uncertainty effects
Correction of tax & fares variations (producers and state net effect)	Split into different components

Table 1 - Separately presented CBA results

Shadow values for labour costs and public funds

The use of shadow values in CBA is often seen as a purely mechanical correction of costs and benefits to remove transfers like taxes. Some countries (for example Italy, as in Table 2) provide in their guidelines the coefficients to be directly used in the analyses performed.

Investment costs	Conversion factor
Civil works (examples)	
- Aqueducts	1.0032
- Sewerage networks, mains, water purification plants	0.9982
- Roads, parks, uncovered sports facilities and markets	1.0254
- Buildings, covered sports facilities and markets	0.9334
- Lighting systems, power lines	0.4600
Building systems	0.8850
Labour	0.7400
Other costs (management, test)	0.8820
Extraordinary maintenance	1.0185
Operating and maintenance costs	
Purchases	0.6480
Ordinary maintenance	1.0182
Other costs	0.7144
Labour	0.5994
Financial returns	0.560

Table 2 – Example of conversion factors provided by the Italian guidelines (NUVV, 2001).

However, the coefficients (or the shadow costs that results from correction) have a deeper meaning. In general, they must be used *“when market prices do not reflect the social opportunity costs of inputs and outputs”* (DG Regio, 2008) to correct such distortions. The lack of coherence between market prices and social opportunity cost of consumed resources is particularly meaningful for two categories of impacts usually accounted in CBA:

- i. the cost of labour;
- ii. the cost of public funds (typically used to finance schemes and policies).

The lack of reflection of social opportunity cost of labour is especially perceivable “in an economy characterised by extensive unemployment or underemployment”, where “the opportunity cost of labour used in the project may be less than the actual wage rates” (DG Regio, 2008). In other words, for example, a net of 1 € spent for a transport investment “costs” to the society less than 1 €, if unemployment exist. The meaning of that is twofold: on the one side it might reflect a political goal of reducing unemployment; on the other side it reflects the macroeconomic effects of public expenditure.

An appropriate set of coefficients is also capable of pointing out geographical differences. For example, Del Bo et al. (2011) estimated values of conversion factors for the EU regions,

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to translate actual observed real wages into shadow wages. In this way, 1 € spent in a region in condition of over-employment “costs” more than 1 € spent in a region suffering of unemployment.

The use of such conversion factor looks promising, as it might allow taking into account the effect of labour into the CBA, (slightly) changing the project ranking, *coeteris paribus*, in favour of regions with higher unemployment. However it must be recognised that the effect of infrastructure spending on employment is more complicated, and a complementary macroeconomic impact analysis is needed for very large investments.

The second type of impact not caught by conventional CBA is related to the social cost of public expenditure. Also in this case changes in flows of public funds resulting from a project (both positive and negative) should be shadow-priced, because the opportunity cost of public funds is higher than the nominal amount involved (Campbell and Brown, 2003). Public revenues, in fact, are obtained from taxes, borrowing or printing money: those methods impose costs on the economy which are not caught by market or shadow-prices and should be corrected with a factor higher than one.

The use of a Marginal Cost of Public Funds, allows also to introduce a “bridge” between financial and economic analysis (Ponti, 2003), modifying the ranking of projects in favour of those which, *ceteris paribus*, require less public resources (for example because generating higher revenues). Moreover the common rule that marginal social cost pricing of transport infrastructure provides the better results in terms of social CBA is reconsidered, in favour of higher cost-recovering pricing looking for an optimal equilibrium in maximising consumers’ surplus and minimising public funds involved (Ponti, 2003).

However, the HEATCO project (2005) outlined that there are reasons not to include the marginal cost of public funds in project appraisal: the large uncertainty on its value; the fact that they are normally not considered when evaluating projects outside the transport sector (and this, according to the authors, would favour decisions against transport projects); because projects that get approved usually show the highest NPVs (and this is, in our opinion, questionable in many countries) and the ratio of NPV and public sector support (RNPSS) can be considered separately (for example, by requiring it to be higher than 1.5).

The treatment of wider economic impacts

Standard CBA quantifies and compares direct benefits with direct costs: time savings, generalized cost changes, consumed resources, etc. In addition, it takes into account also some indirect effects, such as environmental externalities. In many situations, and in particular when the unit benefits introduced by the project are marginal and there are no distortionary effects, these effects capture the totality of economic costs and benefits and, subsequently, a CBA accounting for them is complete. However, in some circumstances, direct and indirect effects are not representative enough of all the effects (Vickerman, 2007; Cohen, 2010): the project is generating welfare greater than directly measured consumers’, producers’, non users’ and state’s surpluses. These effects are usually called Wider Economic Impacts (hereinafter, “WEI”).

Past scientific debate has not been conclusive on some aspects of WEI. In particular, it is not univocally demonstrated the existence of a causal relationship between the increase of infrastructure stock and the increase of economic development of a country. However, the

specific situations in which direct and indirect effects are not sufficient to explain the full effect of a project are nowadays clear (Venables, 2004; Graham, 2007; DfT, 2012, Unit 3.5.14):

- i. Agglomeration economies (changes in localisation patterns reducing costs for firms and households);
- ii. Increased competition and productivity of firms (economies of scale of a firm allowed by a better transport system);
- iii. Changes in the labour market (change in participation rates, increase in the number of working hours, extension of labour market and increase of competition and specialisation of workers).

In addition, some network effects may also rise, whose benefits are not totally captured by users' time savings. Finally, some authors recognise some extra-benefits in the improvement of social cohesion and urban attractiveness. Virckerman (2007) noted that *“such benefits are typically thought of as being positive, but logically they can also be negative implying that the direct user net benefits could over-estimate the value of a project.”*

These effects are complex to model and difficult to generalise. The literature provides some ex-post estimates, but always based on single cases. One of the most complete guideline to the ex-ante estimation of these effects is the already mentioned British guidance (DfT, 2012: Unit 3.5.14). Graham (2007) quantifies the effect on productivity of agglomeration in London. Steer Davies Gleave (2004) reviews sources in which WEI range from 3% to 30% of direct benefits. Copenhagen Economics and Prognos (2004) estimate that, for the Fehmarn Belt Fixed Link, external benefits range from +25% to +52% of direct benefits.¹¹ To the contrary, ex-ante estimations of such effects appear always to be very optimistic if checked ex-post (Bonnafous, 1987; Holl, 2004a e b).

The way these additional benefits must be treated into a CBA must consider these steps:

- a) The analyst must preliminarily (and carefully) check if the general conditions are fulfilled. In particular, schemes radically extending the labour market or allowing a deep reorganization and clusterisation of firms may generate wider economic effects. Projects introducing marginal changes usually hardly do. Wider economic impacts are significant only in specific conditions, typically the solution of extreme problems in urban areas, the construction of missing links, diffused projects in underdeveloped regions. However, in mature and complete networks, in which a degree of accessibility is already guaranteed (typically in developed countries), a new scheme usually improves the situation, but it is often marginal and thus does not generate measurable WEI.¹²
- b) A set of elasticities is needed. For example, it must be firstly estimated the variation of firms densities due to the decrease of generalized costs made possible by the new scheme. The variation of firms' densities, then, determines an increase in firms' productivity, that is a net benefit (DfT, 2012: Unit 3.5.14).

¹¹ The dimension of the effect depends on the radical change in transport performances that such bridge allowed.

¹² This can be seen also intuitively: a project decreasing travel costs of 5 minutes can hardly change the behavior of firms and workers of an area and consequently its benefit is simply the direct time saving.

- c) If no such data are available, some sensitivity tests, based on previous studies, can be carefully used. For example, a rough +20% of direct users' benefits could be added to test how much the results would change.
- d) Given the uncertainty of such estimates, we suggest to keep clearly separate the "standard NPV" and the so called "extended NPV" that includes also the wider economic effects. The eNPV must be carefully tested through a sensitivity analysis. Projects relying only on such effects to pass the threshold of NPV=0 are very weak and unsure and this should be pointed out clearly by the analyst.
- e) Short terms macroeconomic effects, like those occurring during construction, must not be confused with WEI, that are instead related with the changes in the generalized costs and their long term consequences (Berechman and Paaswell, 2005).

In general, one can say that schemes with small direct benefits can hardly be justified on the basis of WEI only, if those are correctly taken into account (i.e. without double counting). Large projects, instead, generate significant external effects under some conditions, but not always. In general, any WEI should be kept separate from standard CBA results, and just used to complement it.

The use of distributive analysis

The key indicators of economic CBA (NPV, BCR, and IRR) refer, by definition, to the society as a whole, ignoring the costs and benefits that refer to single individuals/groups.

The hypothesis at the basis of the acceptability of such indicators is that there is perfect transferability of costs and benefits among constituents of the society. In other words, if one subject is made better off, all will be better off because the benefited one will spread the benefit also to the others. So, a distribution is efficient (or a scheme, when applying CBA) if the welfare gains obtained by some components of society are higher than the welfare losses suffered by others. This is known as called Kaldor-Hicks (K-H) efficiency criterion, and is an extension of Pareto efficiency.

However, if the K-H criterion is not fulfilled, or if we assume that it will become true only in the long run, the distribution of positive or negative impacts among components of the society matters. This is often true in the real world, for example because of monopolies or imperfect redistribution through taxation. In these cases the decision maker might be interested also in the distribution of costs and benefits and not only in the net result.

Theory treated the issue of K-H efficiency few times (Svoboda, 2008). However translations of this concept into CBA of public investments are even rarer (Krutilla, 2005; Morisugi and Ohno, 1995; Campbell and Brown, 2005). The typical approach to distribution into CBAs is the use of Distribution Matrix (or Benefit Incidence Matrix or Kaldor-Hicks matrix). While authors declined the concept slightly differently, the basic idea is the same, namely to disaggregate the NPV of a project into the NPVs of single groups and subgroups involved (Krutilla, 2005; Morisugi and Ohno, 1995; EC-EIB, 2005). The definition of groups is not always unambiguous, due to the existence of different levels of government, geographical grouping and overlapping among groups (e.g.: users are also taxpayers). Some groups will also be indifferent (no benefits or costs) and can be obviously skipped. Others will receive benefits and/or costs and their balance is calculated. The disaggregation can be effectively

represented into a table similar to Table 3, representing the simple case of a project reducing time without generating new traffic.

	Revenues	Time savings	Running costs	Investment cost
Group 1	-30	+300		+270
Group 2	+30		-100	-70
Group 3				-100
	0	+300	-100	-100
				+100

Table 3. Example of Distribution Matrix

The sum per row is the NPV of the group and tells to the policy maker which groups are better and worse off with the project. The sum of the entire matrix is the NPV, as calculated by a traditional CBA. In this example is made evident the hypothesis at the basis of CBA, i.e. the additivity of individuals' surplus into collective surplus:

$$HP: \Delta S = \sum_i \Delta S_i \quad \text{with } i: \text{stakeholders or groups.}$$

The figures in the table come directly must from the CBA model (de Rus, 2010; Campbell and Brown, 2005), where the analyst has already evaluated the various costs and benefits of the project and can assign them to the appropriate group. However, some data could be not available because considered as pure transfers and thus having a zero-sum per column. For example, the revenues could have been ignored in the conventional CBA because transfer from users to service providers (for details see section XX). In this case some further calculations are needed, because changing the sum per row. A further problem arises when some elements can be made explicit only for some groups and not for others. The case of fares is, again, typical: if surplus is calculated with the rule of half, the generalised cost of mode shifters is not calculated completely. So, fares should be visible as benefits for the service provider, but cannot be visualized for users as a cost, because already "embedded" into the generalised cost variation (that, by the way, could be positive overall) (The World Bank, 2005, note 12). In this case a straight representation of Distribution Matrix like the one of Table 3 is impossible and some modifications should be made to keep the sums per rows and per columns coherent. For example, the users of the new project (e.g. a new urban rail) should be divided into those already using the new mode before investment (e.g. those already using existing public transport) and those coming from another mode (e.g. from car). Moreover, it could be necessary to differentiate the new users into a "before" and an "after" situation. Table 4 represents the case of a scheme reducing generalised cost and shifting traffic from concurrent modes. Something similar happens in the case of fuel taxes.

	Revenues	Generalised cost savings	Running costs	Investment cost	
Group 1a: new users of the new scheme (before)	+30				
Group 1a: new users of the new scheme (after)	-30	+100			+100
Group 1b: old users of the new scheme		+200			+200
Group 2	+30		-100		-70
Group 3				-100	-100
	+30	+300	-100	-100	+130

Table 4. Example of Distribution Matrix with shifted traffic

In addition, some complementary analyses can improve the clarity of the results. Firstly, the distribution analysis could have also a geographical dimension, splitting users and other groups as “users of area 1”, etc. This allows taking into account geographical inequalities introduced or solved by a scheme. For example, a new high speed line may benefit users of main cities, but increase generalised costs of users of skipped mid-sized cities, and this can be effectively pointed out by this analysis. Secondly, CEDEX (2010) and Eugenio (2010) suggest representing the ratios of delta surpluses between different groups, which can be used as thresholds for acceptability (see below).

It must be underlined that the table has not any value judgment in it, but it is primarily intended as a descriptive tool. More precisely, a Distributional Analysis accompanying a traditional CBA can have four different purposes, some not mutually exclusive:

- a) A transparency tool: the decision is taken on the basis of standard CBA, in which winners and losers are made explicit.
- b) A further criterion: a certain distribution could be one of the elements of decision, together with total NPV (CEDEX, 2010).
- c) A set of constraints: a certain distribution could be a barrier for a project, despite its NPV (CEDEX, 2010). For example, projects with high ratios between NPVs of different areas or groups could be excluded *ex-ante*.
- d) The basis for weighted CBAs: the distribution matrix could be weighted differently according to the group, obtaining a weighted NPV (Campbell and Brown, 2005). This would reflect the decreasing marginal utility with income of welfare gains. However, this argument is no more used for theoretical and practical reasons (see Eugenio, 2010 for a more detailed discussion) and could even introduce dangerous biases (CEDEX, 2010).

In conclusion, complementing a traditional CBA with a Distribution Matrix detailing the positive and negative effects of a scheme on groups involved is often a worthwhile effort especially in terms of transparency. Those analyses can also better clarify what are efficiency questions as opposed to equity concerns, often (and sometimes intentionally) confused in public debates. The Matrix is sometimes easy to be filled up simply assigning the already determined costs and benefits to the groups. However, in frequent cases, typically when demand is switched from other modes or when generalized cost is calculated as a difference, more effort should be spent to make explicit the distribution without modifying the total NPV.

The use of risk analysis

CBA results strongly depend on input values, in particular construction costs, values of time, expected users, etc. Those values are referred to future situations and are thus affected by a certain degree of uncertainty and risk.¹³ Moreover past evidence showed the existence of an “optimism bias” of planners, modellers and appraisers towards their projects (Flyvbjerg, 2003).

This issue is usually tackled performing appropriate sensitivity analyses with respect to those values whose variation influences results the most or whose uncertainty is higher (usually those who do not have direct market values, like the value of time, external costs, etc.; Maffii et al., 2012). This usually means recalculating the results of the analysis with respect to different input values (usually considering a percentage increase and decrease or using values from other sources or contexts) and finding the so called “switch values” of the inputs, that is those that make the results of analysis change their sign (from positive to negative or the opposite). The analysis is often performed by changing many values together in different scenarios.

However sensitivity analysis cannot take into account the probability of such variations in input values. When the distribution of probabilities is known, a risk analysis can be performed. The distribution of probabilities can be modelled using different functions, as shown in Figure 3.

¹³ Uncertainty and risks are different: risk can be defined as the range of possible values an input can assume, whose probability distribution is known, while uncertainty means that the probability distribution is unknown (DG Regio, 2008; Maffii et al., 2012).

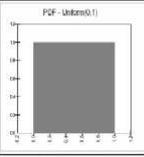
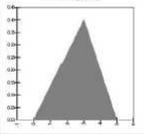
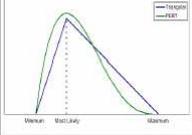
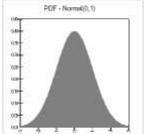
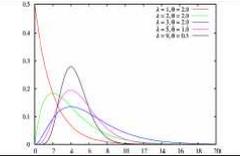
Distribution	Illustration	Properties	Framework
Uniform: Safety unit costs		Close ended Equal probability	Equal possibility of under- and overestimating the most likely value with $\pm 10\%$
Triangular: Maintenance Unit costs		Close ended Possibility of skewness	Possibility of respectively under-estimation of ML is [-10% ; ML ; +50%]
Beta (PERT): Maintenance Unit costs		Close ended Possibility of skewness	Possibility of respectively under-estimation of ML is [-10% ; ML ; +50%]
Normal: Travel time savings		Close ended No skewness possible	Most likely value is set to first year impact, std. dev. is set to 15%
Gamma (Erlang): Construction costs		Semi-close ended (open to the right) Possibility of skewness	k-value is set to 5 and θ is calculated on basis of the mean from Lichtenberg [-25% ; ML ; +100%]

Figure 3 - Example of different distribution of probabilities used in risk analyses in Denmark (Salling, 2007).

Starting from those expected probability distribution of input value it is possible, using the Monte Carlo method (Salling, 2007), to estimate the probability distribution of the results of the analysis, typically the NPV. Results are usually calculated in the form of probability distribution or cumulated probability, together with the value of the resulting weighted average NPV (DG Regio, 2008).

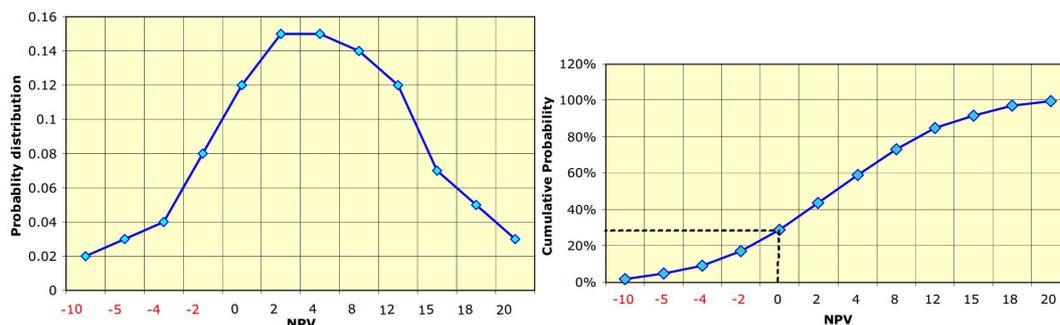


Figure 4- Example of probability distribution (on the left) and cumulative probability (on the right) of the NPV (DG Regio, 2008).

Unfortunately, in contexts where data lacks – which is the case in many countries with short or no CBA tradition – it is usually very difficult to find and estimate central values for many inputs, and obtaining information on the probability distribution is thus unrealistic. Moreover, considering that the commonly used probability distributions of costs and expected demand are not normally distributed, underlying the possibility of an optimism bias by the appraisers (Flyvbjerg, 2003), some concerns could be expressed if the appraisers themselves perform those risk analysis (in a way, this might mean they are admitting and confirming their bias). This issue might be more significant in countries where projects are evaluated one by one by

different proposers (e.g. the UK, France, Italy), rather than where projects are evaluated altogether during the planning stage (e.g. Germany, The Netherlands, Sweden) (Beria et al., 2012). In general, we think that it is important to display the potential range of error, but formalisation seems not to be always needed, due to the effort required to produce coherent results.

CONCLUSIONS

This paper focused on some issues that appear to be still unresolved in the yet generally consolidated CBA of transport projects practice, in the light of the most recent contributions in the literature.

“Standard” CBA aims at providing indications about the socio-economic efficiency of considered projects, focusing on the first order effects. Theory appears consolidated, but some controversies still seem to exist, related to the evaluation of mode shifting users’ surplus and the treatment of taxes and additional revenues due to mode shift. We provided an interpretation, based on the most consolidated theory.

Moreover, “advanced” CBA – whose results we suggest to keep separate from those of standard CBA – can catch other important aspects, such as macroeconomic and financial second order effects, equity issues, uncertainty and risk. In our paper we provided an analysis on the state of the art of such advancements, with some comments and suggestions for practitioners.

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