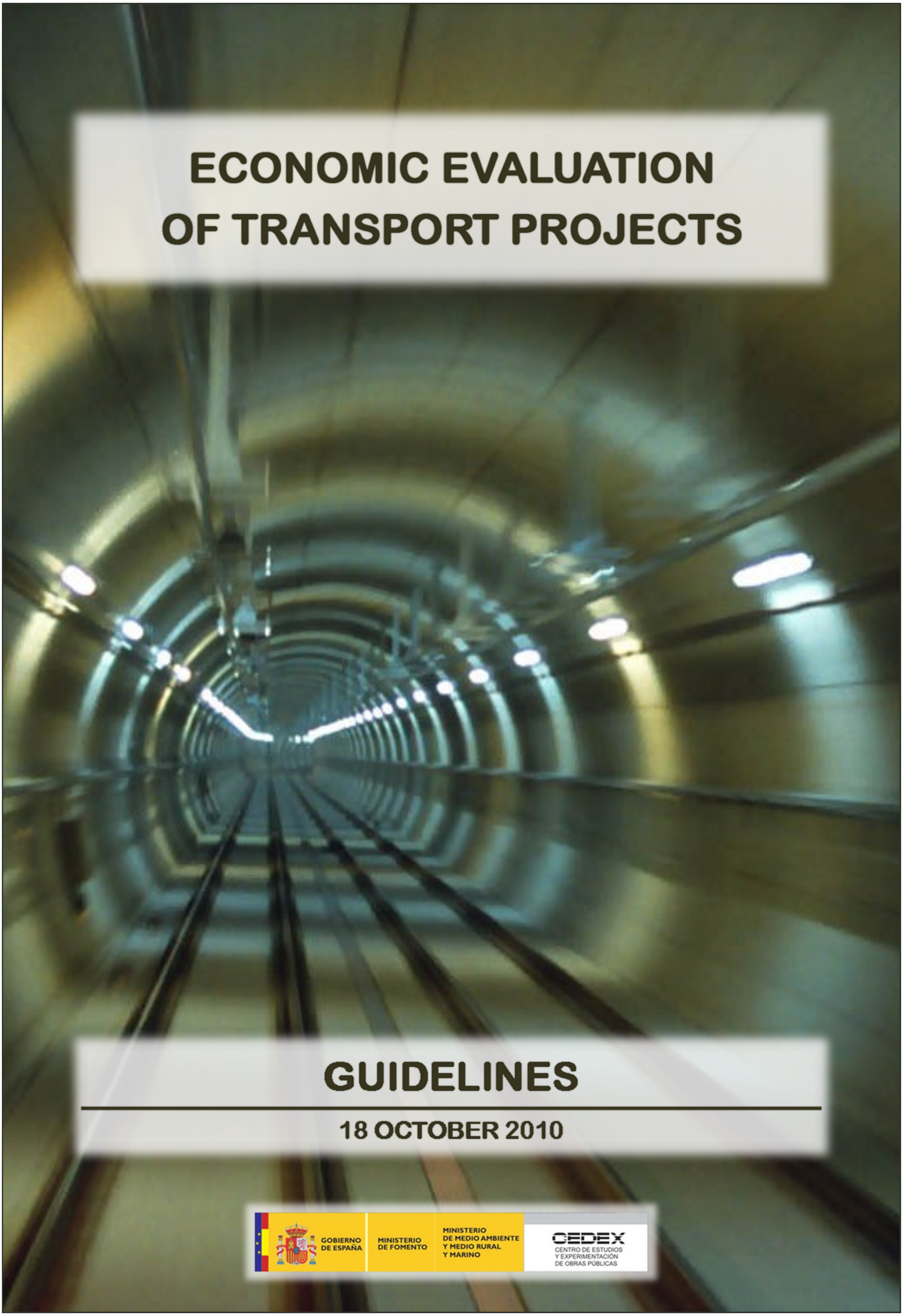

ECONOMIC EVALUATION OF TRANSPORT PROJECTS

GUIDELINES

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GOBIERNO DE ESPAÑA
MINISTERIO DE FOMENTO
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Project: **SOCIO-ECONOMIC AND FINANCIAL EVALUATION OF TRANSPORT PROJECTS**

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Summary

This GUIDE ON ECONOMIC EVALUATION OF TRANSPORT PROJECTS is the result of the research project entitled **Socioeconomic and financial evaluation of transport projects** (PT2007-001-IAPP) funded by the *Centro de Estudios y Experimentación de Obras Públicas (CEDEX)* of the *Ministerio de Fomento* within the 2007 Program for Scientific Research Projects linked to the Strategic Plan of Infrastructure and Transportation in the framework of the National Plan of Scientific Research, Technological Development and Innovation 2004-2007 (B.O.E. April 16, 2007).

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Main abbreviations and symbols

p	Price
q	Quantity
g	Generalized price
v	Value of time
τ	(Total) Time of travel
θ	Monetary value of quality
K	Capital (factor of production)
L	Labor (factor of production)
N	Natural resources or other resources
E	Mobile equipment (vehicles)
R	Energy consumption and spare parts
C_S	Social costs of transport
C_P	Producers' costs
C_U	Users' costs
C_{RS}	Costs of the rest of society
NPV	Net present value
NPV_{S}	Social net present value
NPV_{F}	Financial net present value
t	Each of the time periods in which the project is divided (years)
T	Total duration of the project in years
ΔBS_t	Change in social benefits (in period t)
ΔBP_t	Change in private benefits (in period t)
I	Discount rate (real)
i_n	Discount rate (nominal)
φ	Inflation rate
IRR	Internal rate of return
F_{NPV}	NPV distribution function
X	Minimum NPV_F required to a project
SS	Social surplus
CS	Consumer (or user) surplus
PS	Producers surplus
GS	Taxpayers surplus
RSS	Rest of society surplus

Contents

1. INTRODUCTION

The main objective of the economic appraisal of a transport project is to identify and quantify the project's contribution to social welfare. This **GUIDE** starts from the idea that public investment in transport infrastructure and services should be assessed using cost–benefit analysis (CBA). The existence of an opportunity cost for social resources implies that society as a whole should always consider whether what it gains from the project exceeds what it might have obtained allocating the same resources to alternative uses. This **GUIDE** has been written for use by economists, engineers and other professionals in public administration and, although it has made an effort to define the proposed methodology using simple rules, it also assumes that the user has a basic knowledge of economics.

The **transport system** of a society can be analyzed from two perspectives: on the one hand, it can be seen as a set of technical relationships seeking the most effective use of productive resources available to any society to move people and goods among different places; and, on the other hand, it is also a set of economic relations that aims to organize these movements in the most efficient way, i.e. allocating the resources to globally achieve the highest social welfare.

Both approaches complement each other and their integration will decide whether a society gains a transportation system that adequately satisfies its needs or not. This integration is performed through **transport markets**, where different social agents, who demand and supply infrastructure and services, interact within the set of exchange opportunities provided by the existing technology, and the institutional framework governing their relationships.

The result of this interaction is a particular allocation of productive resources in the form of certain levels of provision and the use of infrastructure and transport services, which in turn leads to a certain level of social welfare. This initial equilibrium without project varies over time, either through the natural evolution of the economic agents' behaviors or as a result of external interventions in the markets.

Thus, the term ***transport project*** refers throughout this **GUIDE** to any type of intervention in a transport market that, by modifying the initial equilibrium without project, changes the agents' welfare and thereby the level of social welfare. Each transport project aims to achieve a certain result in the transport system. Obviously, the pursuit of the same outcomes can be carried out through alternative projects. Although this concept has been traditionally reserved for investment in infrastructure projects, many other types of policies (price regulation, changes in services conditions, etc.) can be analyzed from the same perspective, i.e. assessing their contribution to the efficient functioning of the transport system as a whole.

All transport projects share a common feature: when society allocates resources for the implementation of any of them, it is simultaneously renouncing the benefits that would have been earned if those resources had been devoted to other needs. Thus, taking into account the fact that the resources available in any society are scarce, it is clear *ex ante* (before approving a project) that the projects' expected benefits should be compared with the projects' **opportunity costs**. If the social benefits of a transportation project are greater than the benefits given up by the society in the best available alternative, then it can be safely said that the project contributes to increasing social welfare.

Such evaluation is not only useful *ex ante*, but also once the project is running (*in medias res*), or even when it is completed (*ex post*). In these cases, project evaluation is not about deciding whether or not to carry out the project, but whether it should be amended (provided the new information available) or not; or about extracting lessons that could improve the design of future projects. Again, the purpose of evaluation from the point of view of efficiency would be to improve **the welfare of society**.

On the other hand, any reallocation of resources as a result of a transport project always entails a certain social welfare level associated with a particular distribution of the income that is collected by the owners of those resources. This distribution can imply the existence of groups of people or geographic areas with different income levels. In many cases, society considers that the redistributive effects associated with such a distribution are inadequate. When this happens, it is possible to consider transportation projects whose main objective is not to achieve higher efficiency, but aims to personally or spatially redistribute income.

However, project evaluation from this point of view is always more complex because of the lack of consensus about the definition of fair income distribution and the overall treatment of equity. For this reason, **the goal of efficiently generally prevails** in all processes of **economic evaluation**. Yet, when a project has a significant impact on equity, any evaluation should try – as far as possible – to measure the benefits and costs obtained by each of the different economic agents involved or affected by it. This would facilitate, for instance, the design of potential compensatory actions to mitigate the damage suffered by certain groups or territories as a result of socially desirable projects, or even the introduction of mechanisms relating the contribution of each of these agents to a project with the benefits and costs obtained from it.

CBA is a well-established technique intended to carry out the economic evaluation of projects by expressing their benefits and costs in a common unit, based upon the intensity of the preferences of the individuals with regard to goods and services in a broad sense. Since economists have developed techniques to measure these preferences in monetary equivalents, they can be expressed in monetary values, which facilitate comparisons.

In fact, CBA has been fruitfully applied in the field of transport because assigning monetary values to the benefits and costs of a transportation project is generally easier and less controversial in this field than with other policies or projects.

However, transport markets are highly heterogeneous because they are organized by modes (land, air and sea) with different technical characteristics and operational rules. Therefore, there are many possible potential interventions or projects in these markets: examples of transport projects include from building or refurnishing different types of infrastructures (roads, railways, ports and airports) to changes in certain transport services (implementation of high-speed rail, opening or closure of lines, etc.) including pricing policies or other measures related to the safety or quality of services, or any combination of all the above, either in the same mode or in several of them together.

Despite this diversity, the economic evaluation of most transport projects can be approached from a set of **common principles** designed to measure and quantify the project contribution to social welfare from the point of view of efficiency and, where appropriate, equity. These general principles **can be adapted to any particular project**, thereby providing a comparable procedure and a common reference framework for analyzing the operation of the transport system in any society.

There also exist other manuals and reference guides in which different national and international bodies have established their own evaluation criteria. Most of these documents start by dividing the evaluation process into several stages – not always with the same degree of aggregation or order of implementation – ranging from project definition to decision-making. Then, each manual also provides a set of general guidelines and practical rules to evaluate each transportation project in particular.[1]

Although many of these principles are well-known in the CBA literature, there persist some notable differences in their applications to certain aspects of the economic evaluation of transport projects. These differences include issues related to the objectives of the process, the definition of projects or the methods for calculating benefits and costs. There are also different treatments of direct and indirect benefits, environmental costs and the uncertainty associated with each project. Likewise, it is rare to find specific recommendations about the problems of forecasting demand or the lack of infrastructure capacity, as well as a detailed discussion of the role of equity considerations and institutional design throughout the evaluation process.

In this **GUIDE**, we have opted to divide the economic evaluation of projects into the six stages shown in *Figure 1.1*, which also defines the structure of this **GUIDE** from now onwards.

In ***Chapter 2***, we analyze the **project definition** and how it relates to the institutional framework in which it is located. The aim in this chapter is to identify the objectives of each project, i.e. make clear the specific transport problems to be solved through intervention in the transport markets within the overall context set by the economic policy. The definition of the project involves not only considering the technically feasible alternatives to achieve those objectives, but also analyzing the effects arising from them and which agents are affected in each case.

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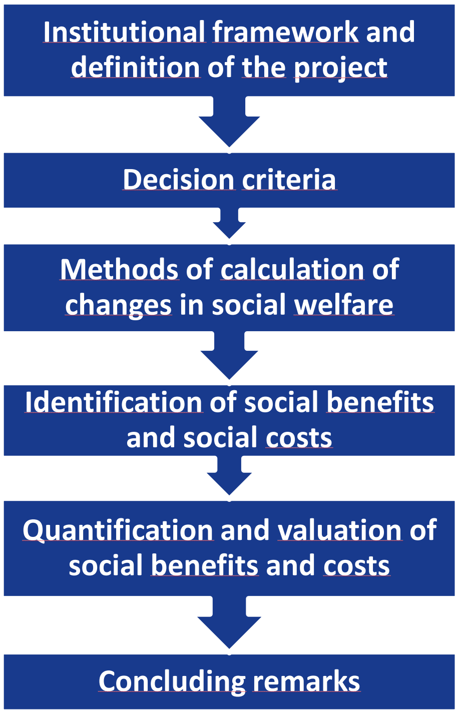
[1] In the working paper (in Spanish) "Manuales y procedimientos para la evaluación de proyectos de transporte", there is a review of these guides. Among them, we particularly emphasize **EIB (2007)** and **European Commission (2008)**.

Figure 1.1: **The process of economic evaluation of projects**



From this definition, ***Chapter 3*** discusses the **decision criteria** that can be used to accept or reject transport projects. Although in many manuals this discussion is treated as the final stage of the evaluation process, its close relationship with the institutional framework surrounding the project definition allows us to suggest that such criteria should be made explicit from the beginning of the process, clearly distinguishing between the economic (or socioeconomic)[2] evaluation and the financial evaluation. Traditionally, decisions are based on a deterministic comparison between benefits and costs provided by each project over time, sometimes incorporating a sensitivity analysis about the project outcomes or scenarios to reflect possible changes in the overall circumstances. However, experience shows that any evaluation is a complex process, often performed with incomplete information, because of the uncertainty associated with future demand or costs, the lack of certain technical or economic parameters of the project or even unforeseen opportunistic behaviors and unpredictable actions by the agents involved. For these reasons, this **GUIDE** incorporates uncertainty into the evaluation process from the beginning, introducing it as a key element in the decision criteria.

Once the project and decision criteria have been defined, ***Chapter 4*** addresses the practical implications that each project has on social welfare. Two approaches are developed to calculate the **change in social welfare** that is generated as a result of any intervention in transport markets. The first approach implies calculating the change in the allocation of productive resources (and the willingness to pay (WTP) for them) with which different agents contribute to the economic

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[2] Both terms are used interchangeably because we are comparing social benefits and social costs.

activities taking place in transport markets. The second involves analyzing the change in each agent's economic surplus as a result of the changes introduced by this project. Although different, both approaches are equivalent and should lead to the same measurement, since the equilibrium in any market can always be interpreted from those two perspectives: allocation of resources and income distribution.

Chapter 5 discusses in more detail the **identification** of each of the benefits and social costs of a transport project. We first provide a detailed list of the benefits and costs of any transport project, and then analyze their main characteristics and how to incorporate them into the evaluation process. Within the social costs and benefits considered, and besides investment costs, we include the time savings for existing users, the changes in operating costs and the maintenance of infrastructure and services, the changes in external costs and benefits (including safety and environmental effects), the improvements in the quality of services provided and the value generated by the project to new users.

Each of these items poses particular problems for the **quantification and monetary valuation** that is discussed in detail in ***Chapter 6***. This analysis particularly affects the users' and producers' costs, and it is essential to distinguish between the categories to understand the different valuation techniques to use in each case. It can be possible to use market values (prices) by introducing appropriate correction factors to reflect the project impact on social welfare. In cases where there are no markets (as with external effects, such as pollution), the evaluation must necessarily use alternative estimates. The transfer of values from other studies or surveys or other ad hoc studies is also discussed in this chapter.

After the identification, quantification and valuation of all the benefits and social costs of a project, the evaluation process formally concludes by applying the decision criteria previously agreed. ***Chapter 7*** presents some **concluding remarks** about the evaluation process, addressing, in summary, issues related to the institutional framework for the economic evaluation of projects, possible errors and biases that should be avoided, and general and specific recommendations for this process to be useful for decision-makers and society as a whole.

Finally, there are some additional elements in the economic evaluation of transport projects that, despite being included in the earlier stages, require more detailed discussion and additional information that goes beyond the general objectives of the **GUIDE**. Therefore, in addition to the supplementary material that can be found on the website ***www.evaluaciondeproyectos.es*** (both in Spanish and English), we decided to include some appendices in this **GUIDE** to specifically address the main implications of these issues.

Appendix I explores the role of **demand forecasting** in the evaluation of transport projects. Because evidence shows significant prediction errors, this section provides an account of the various elements to consider in order to minimize them. In particular, starting with a discussion of the fundamentals of the problem of demand forecasting, this section presents the main techniques for the prediction of traffic, analyzing the advantages and disadvantages of each in the context of project evaluation.

Appendix II addresses the procedures for the **measurement and valuation of external effects**, positive and negative, associated with transport projects. Although these effects can generate substantial changes in social welfare, the difficulty of rating elements for which there is no market (such as pollution or the statistical value of life) can lead to the decision to ignore them or estimate them incorrectly. The challenge in this area is to differentiate the effects that can reasonably be measured and monetarized from those for which a qualitative description might be more useful than a bad measurement or a transfer of values obtained in incomparable situations.

Appendix III studies in more detail the **impact of transportation projects on equity**, both referring to personal income distribution and the effects on the territory. There are projects whose costs and benefits are equally shared among the agents involved without causing significant equity problems, but other projects harm or benefit asymmetrically different income groups or geographical areas.

Appendix IV analyzes two elements related to the **institutional design** of the evaluation process that are only touched on in previous chapters. The first one, from an aggregate perspective, analyzes the institutional relationships among the different levels of public administration and how these relationships affect the proper selection of transportation projects. The second, from a disaggregated perspective, analyzes the contractual relationships established among the different agents involved in a project and how they determine agents' incentives. For example, the behavior of a highway concessionaire is determined by the clauses relating to revenues and costs that appear in the contract, which in turn is part of the evaluation process.

Finally, it should be stressed again that this document focuses on the *economic* evaluation of projects and its ultimate goal is to estimate the change in social welfare arising from the implementation of a project. Owing to information problems and uncertainty of a different nature, the aim of this **GUIDE** is to provide the decision-maker a tool to reasonably distinguish between projects that are socially desirable and projects that are not.

2. PROJECT DEFINITION

2.1. What is a transportation project?

Transport projects affect the functioning of markets either by building or changing infrastructure or by modifying the services provided for them. Constructing new roads, upgrading existing networks, extending ports or airports or implementing high-speed rail services are traditional examples of transport projects. However, even though their characteristics are different, so are changes in pricing policies or any other change in the conditions of service provision or operation of infrastructure.

> Any **transportation project** can be defined as an **intervention** on a **transport market** that shifts the equilibrium that would have been achieved in this market and the rest of the economy if there had been no such intervention.

The evaluation of the project will then consist of an exercise of equilibrium comparisons through which its effects on society can be assessed. Evaluating is, therefore, equivalent to analyzing the different levels of social welfare achieved with a transport project (taking into account all its implications from the beginning until all its effects wear off) compared with the situation without the project, i.e. what would have happened if the project had not been carried out.

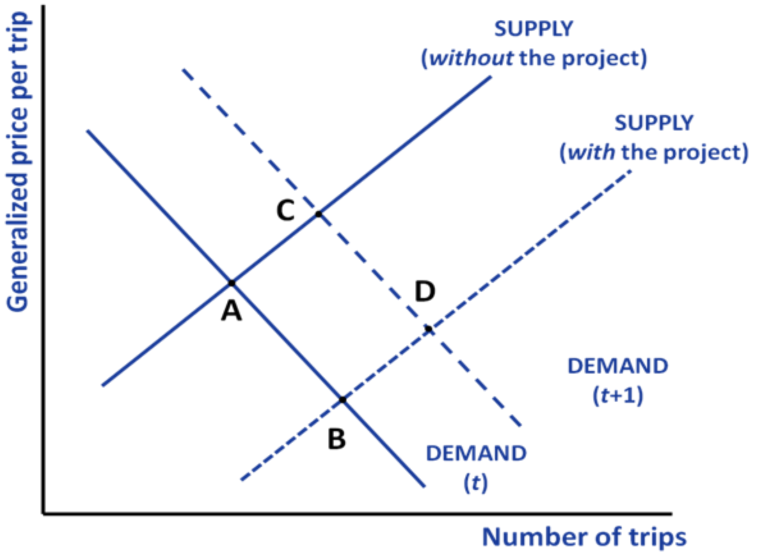
Determining the effects of a project

Transport market equilibrium is generally expressed as the total number of trips (or number of passengers or goods carried) during a period and the generalized price *paid* by the users. This generalized price includes, in addition to a monetary component (prices, fares, tolls, etc.), the value of travel time and other monetary valuations of disutility (discomfort, the risk of luggage loss or damage of goods). The economic evaluation of a project will identify the positive (benefits) and negative (costs) effects of changes on social welfare as a consequence of the changes in the equilibrium introduced by the project.

Furthermore, because most interventions in transport markets span **several time periods**, the equilibria comparison must also be performed in each of them, taking into account both the changes produced by the project and the changes that would happen in the markets if the project does not take place.

> The economic evaluation of a transportation project must be carried out **incrementally**, i.e. comparing the equilibrium achieved in the transport markets *with the project* and the initial situation in those markets *without*.

Figure 2.1: **The evaluation as a comparison of equilibria**



These ideas are illustrated in *Figure 2.1*. Consider, for example, an intercity transport market for passengers. The demand function reflects the negative relationship between the number of trips that users want to make and the generalized price (which includes, among other factors, fares and the value of travel time). Assume also that this demand grows over time in response to changes in exogenous factors such as the increase in income and population size. On the other hand, consider that the supply function is increasing because of, for example, the presence of some degree of congestion that results in an increase in travel time when the number of trips increases. Point **A** is the initial market equilibrium (*without* project), determining the price and number of trips by the intersection between the demand in the baseline period (period *t*) and the initial supply function.

Suppose now that in period *t* a transport project is carried out and this increases the supply of travel services in the same period. Graphically, this would imply a rightward shift of the initial supply function, to gain the new supply *with* project, and a new equilibrium, defined by **B**. Therefore, the social benefits and costs of this project at time *t* would be obtained by comparing the **A** and **B** equilibria.

This measurement is not enough: we cannot ignore the changes that would occur in the market regardless of whether the project was undertaken or not. For example, the previous figure also represented the demand function in a later period (t + 1), which would have shifted to the right. This new demand function at t + 1 allows us to obtain both equilibrium without project (**C**) and equilibrium with project (**D**). Determining the effects of the project at t + 1 should be performed by comparing the two latter equilibria precisely because these really reflect the impact it has on the market. The equilibrium represented at point **C** is a *counterfactual*.

This same procedure should be repeated over time to determine the positive and negative impacts of the project in each of the subsequent periods, as long as the consequences of the initial intervention remain in the market.

Indirect effects and additional economic effects

In addition to being distributed over time, the effects of a transportation project are not necessarily limited to the **primary markets** (those in which the intervention occurs) represented in Figure 2.1, since it often also has an impact on other markets related to the primary (**secondary markets**) and on global economic activity (**additional economic effects**).

> In determining the effects of a transportation project, we typically distinguish between **direct and indirect effects** and what are often referred to as **additional economic effects**.

In principle, the **direct effects** of a transportation project must be sought in the market where the intervention takes place, departing from the identification of all agents affected by it. Therefore, the effects will be determined by the extent used in the definition of the transport project.

For its part, the **indirect effects** appear in the markets (secondary) whose products or services have a complementarity or substitutability relationship with the primary market and where there is some distortion that prevents the price being equal to the marginal cost. In many transport projects, it is usual that any intervention in a particular mode affects modal distribution, significantly affecting other transport markets where there can be congestion, externalities and so on.

In addition to the aforementioned effects of *competition and intermodal complementarity* produced in other transport modes, there can also exist indirect effects in other economic activities that use transportation as part of its supply chain (for example, tourism).

In many cases, indirect effects can be ignored if the secondary markets are reasonably competitive or, even with distortions, the magnitude of the effects are not significant. As a general criterion, **indirect effects can be ignored if there are no significant distortions on secondary markets** and the demand–supply interaction is frictionless. The underlying assumption behind this recommendation lies in considering that the marginal contribution of these effects to social benefit equals its marginal effect on social cost, which tends to be correct to the extent that these markets (of products and factors) operate competitively (no distortions caused by subsidies or taxes, absence of barriers to entry or externalities, etc.). When this does not happen in a secondary market in which there are significant indirect effects, they should be measured and incorporated into the evaluation (for example, the impact on a congested airport infrastructure if a new railway line that diverts air traffic is built).

Finally, sometimes it is also discussed whether to include in a project evaluation other possible indirect effects of a more aggregated nature, which try to capture the impact of the project on the overall economic activity. They are often expressed in terms of "improvements in competitiveness" or "ability to attract new investments." So far, there is no generally accepted consensus in the literature regarding the treatment of these **additional economic effects**, which are primarily associated with factors such as economies of scale or agglomeration, or the long run responses of social agents to the improvements in the transport system.

It is always difficult to determine a priori the sign and magnitude of these effects, which also often differ between projects. Therefore, in *small projects* it is preferable to ignore them, even if this risks biasing the outcome of the evaluation if they really existed. There is a broad agreement that this risk is offset by the elimination of the (even higher) risk of double-counting and the delay costs in the project evaluation because of their measurement. For large projects or the evaluation of aggregate investment programs, it could be reasonable to undertake more sophisticated analysis of a macroeconomic nature.[3]

- The **direct effects** of a project are those that affect the equilibrium in the primary market and the economic agents operating in it.
- **Indirect effects** appear in secondary markets related in terms of complementarity or substitutability with the primary market, and usually can be ignored if there are no significant distortions in these markets.
- **Additional economic effects** are aggregated and their sign is often uncertain and difficult to quantify, so ignoring them is advisable in small projects.

A standard result in the evaluation of investment projects in transport infrastructure is that if the effects of improved transport services have an impact on competitive markets that use those services as an input, we can concentrate evaluation efforts in the transport market affected by the change, ignoring what happens in the markets that use those services.

This does not mean that companies in other markets that use transport services do not benefit from the project that reduces their transport costs or that consumers do not benefit from lower prices. It is simply to avoid double-counting the same effect, since the benefits of reducing those costs have already been assessed in the primary transport market.

Assuming that information is available for both markets, the project effects can be measured either on the final markets for goods and services or, alternatively, in the transport markets, but not in both (double-counting error). In practice, it is easier to measure the effect on the transport market

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[3] This issue is addressed in more detail in the working paper "Indirect effects and additional economic benefits."

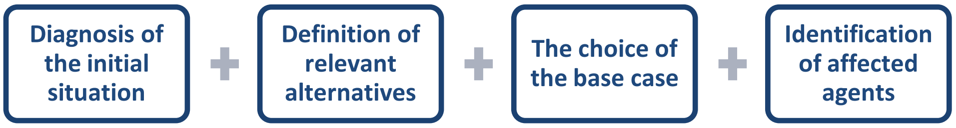
since most companies and markets use transport services as an input. In the final markets, it is generally more complicated and expensive to obtain the necessary information.

Avoiding the double-counting of benefits and costs should be a major concern in the evaluation process. This concern is also applicable when analyzing the effects of transportation projects on the housing market because the market value of land, housing or local trade changes as the characteristics of the transport infrastructure and services around them change. Generally, these value changes should not be included in the project evaluation since they have already been measured using the derived demand for transport. Their inclusion would again imply double-counting.

2.2. Elements in the definition of a transport project

Once the procedures for determining the direct and indirect effects of a transport project have been established, the first step in the evaluation process is to accurately define the project. This requires the completion of at least the four elements described in *Figure 2.2*.

Figure 2.2: **Elements in the definition of a transportation project**



Diagnosis of the initial situation

From the point of view of economic evaluation, any intervention in transport markets should have its origin in society's recognition that the functioning of these markets without intervention would lead to worse results than those obtained with the intervention. The improvement involved in the project can be interpreted in broad terms, such as the reduction of congestion or number and severity of accidents. In general, most interventions are justified by appealing to *efficiency* arguments, considering that the current allocation of resources is improved, with lower generalized prices and/or better service levels. In other cases – although its evaluation is difficult – reasons of *equity* are adduced to justify the project, considering, for example, the need to protect or promote a particular social group or territory by improving their transport conditions. Whatever the reason used to justify the project it must always be based on the previous diagnosis of an initial situation in which we explicitly detected possible improvements to achieve, since a **transport project should never be an end in itself**, but a means to improve social welfare.

This initial diagnosis leads to an additional restriction in the definition of transport projects: they should pursue **specific objectives related to the functioning of transport markets**, such as reducing travel times, reducing transport costs or increasing the frequencies or capacity provided.

A project contributes to social welfare to the extent that the benefits generated by solving an existing problem in that market exceed the costs of the intervention.

If there is no problem it is difficult to generate profits, and the intervention represents only a cost to society in both the short- and long-term because we must not only meet the investment costs but also the operation and maintenance costs. On the other hand, if we want the project to achieve objectives in markets other than those of transport, it is precisely in those markets where the intervention should be formulated so that these results are achieved through appropriate instruments.

In this sense, transport projects are part of the sectoral and general economic policy of a country and are heavily influenced by the institutional framework in which the relationships among the different agents are developed. This linkage is also necessary because **raising a project regardless of its relationship with other plans and actions of the public and private sector could lead to conflict with other interventions already made or planned for the future.**

The public planning of infrastructure and transport services is an essential tool for the definition of transport projects, since they are generally defined on the basis of a previous diagnosis of the main problems and establish at the same time general objectives of reference which, when followed consistently, give to the transport projects consistency and effectiveness.

> The **definition of a transport project** should allow the identification, in simple terms, of the **transportation problem** that society is attempting to solve with its implementation and the alternative chosen for this purpose.

Definition of relevant alternatives

Simultaneously with the definition of a project, the identification of the markets and actors involved, the discussion of the objectives it seeks to achieve and an acknowledgement of the alternatives available to solve it should also be considered. If this process is performed in an incorrect or incomplete manner – either considering impossible or irrelevant alternatives or ignoring the existence of other actions that could achieve the same results – economic evaluation cannot fulfill its function of identifying what actions contribute to improving social welfare.

The evaluator's position within the institutional framework and the degree of discretion that is granted to him determines the scope of the alternatives considered. For example, when an evaluator is asked to evaluate a specific road construction, most of the alternatives will be related to the design or construction of technical procedures; on the contrary, if the evaluator is given greater discretion, asking, for example, to solve the problem of connecting two cities, the alternatives to be considered will be more open and include, besides the road, many other transport policy options.

The institutional design of the evaluation process itself can also generate some perverse incentives in relation to the scope of the proposed alternatives. As discussed in greater detail in ***Appendix IV***, when there is a separation between those who finance the project and those who benefit from it, the latter tend to make more ambitious alternatives, unless the mechanisms of responsibility (for example, cofinancing the project) are introduced to reduce this problem of asymmetric information. Similarly, when project funding is separated from its contents and objectives, and based on other reasons, the alternatives are rarely defined in a sufficiently exhaustive way, but often focus instead on the specific objective pursued, which is not always the solution to a transportation problem.

The role played by technology in the definition of a project's alternatives should be viewed as a multidisciplinary field in which sectoral experts should always participate to ensure the identification of all technically feasible options that should be considered. Although the benefits of technological progress are undeniable, from the perspective of economic analysis and based on the concept of opportunity cost, it does not always make sense to choose the latest or most expensive technology. Sometimes, the proper maintenance or minor improvement of existing technology can contribute more to social welfare than a more technologically advanced option: in the economic evaluation of a project, the technology is also a means, never an end in itself. The institutional design of the evaluation process can again generate some perverse incentives regarding the choice of technology to use in a particular transportation project. When there is a separation between those who finance the project and those who benefit from it, the latter tend to choose, regardless of its suitability, the most expensive technology.

> The discussion of relevant alternatives is a crucial step that is subject to the discretion held by the evaluator. The scope of **project alternatives** is conditioned by the **institutional framework** within which the evaluation process arises and the **technology available** at any time. Ignoring viable alternatives in the evaluation can generate significant errors.

The choice of the base case

Project evaluation must be completed incrementally, comparing each proposed solution (situation *with project*) with a **base or reference case** (situation *without project*) and evaluating the differences in the benefits and costs among the possible options as proposed in *Figure 2.1*.

Depending on the type of project considered and the information available, the base case can be to carry out "minimal actions" on the current situation (for example, capacity expansion projects) or even "do nothing new" (maintenance projects). As already indicated, the situation *without project* is not the same as considering that the current conditions remain constant, but assumes that the initial equilibrium is projected into the future with the corresponding changes in demand and supply.

The **base case** is the benchmark used to compare what would have happened *without* the project; therefore, it cannot have a static character but must incorporate what would have been the evolution of the markets affected by the project if it had not been performed.

We should assess the relevant alternatives to solve the problem identified in the initial diagnosis, since failure to consider relevant alternatives could lead to investment in a project that yields a positive social return *ex ante* but that is not the best solution to the transportation problem. This makes the choice of base case crucial for the evaluation: since the benefits are obtained by incremental comparison with the baseline established in that case, the worse the reference of comparison the more attractive the project seems (and vice versa).

All elements that determine the definition of a project are ultimately constrained by the time when the evaluation is performed. When it takes place before implementing the project (*ex ante*), the range of possible alternatives is often wide, although the specific information on each of them tends to be limited. The number of alternatives is reduced and the information increases when evaluations are made *in media res* (during the execution of the project), whereas the final evaluation (*ex post*) focuses on the results achieved by the alternative implemented, with all the information available.

Identification of affected agents

With few exceptions (such as leisure travel), the services offered in transport markets are not demanded by themselves, but to move people and goods between different places to trade them in other markets and activities. However, it is not practical or feasible to consider all the implications of the functioning of transport markets into all other markets that they feed. This does not mean that consumers and producers in these markets do not benefit from a project, for example, that reduces transport costs and lowers prices in those markets. On the contrary, these consumers and producers are, in principle, the final beneficiaries of the transport project, and since the change that occurs in social welfare seems to be reflected in the derived demand for transportation, it is usually measured through it.

In general, and although the degree of aggregation can vary with each project, it is important to consider as a starting point at least the following groups of agents:

- **The users of transport services and infrastructure**, as consumers of such services and infrastructure (passenger transport) or owners or consignees of goods using these services or infrastructure (freight transport). They might be individuals, social groups or even other companies that are included in the derived demand for transport.

- **The producers of transport services and infrastructure**, generally public or private companies, which make available to users such services or infrastructure. In some cases, producers are also users since they serve themselves.

  It should be noted that the term "producer" includes operators that make use of productive resources that either provide themselves or acquire in factor markets.

  To the extent that the evaluation requires it – and especially when it is necessary to identify the final recipients of the benefits and costs of a project by equity issues or the funding of projects – it can be advisable to distinguish within producers between the **owners of capital, labor and land**.[4]

- **Taxpayers**, in cases where the project will produce changes in taxes and subsidies that alter the fiscal balance.

- **The rest of society**, a group that includes the not internalized external effects.

These groups are not mutually exclusive. An individual can simultaneously belong to several of them. For example, a shareholder of a transport firm might be a consumer of the goods transported whose price changes and might also contribute as a taxpayer to finance the project.

It is important to reasonably restrict the **extent to which we define the scope of the project**. If the definition is overly broad, an overall positive evaluation could hide projects that would not be socially acceptable when evaluated separately. It is not recommended to submit to evaluation an aggregated project that, in reality, constitutes the sum of individual projects perfectly separable; although it is also not advisable to use a technically unfeasible level of disaggregation (e.g. splitting a project that would not be feasible if other projects were not implemented together).

> The **project must include** all the elements needed for its operation (e.g. access road in a port) and exclude elements that are perfectly separable projects. The exclusion of required components can fictitiously raise profitability. The inclusion of separable projects can offer an average profitability that conceals the profitability of each individual project.

On the other hand, the identification of markets also requires a definition, although only implicitly, of what parts of society are affected by the project and whose benefits and costs will be considered. The identification of markets does not always coincide with that of the agents. The general rule is not to analyze where the effects of the project are, but instead to focus on **who**

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[4] When this degree of disaggregation is unnecessary, or when its use leads to confusion, it should also be added using the concept of "producer."

provides the resources necessary for them to take place. For example, in projects at the local or regional level supported by national funds, it is the welfare of the country's society as a whole that should be considered for evaluation because they are the agents who assume the opportunity cost in foregone alternatives of undertaking this project.

Similarly, in projects of national scope and funding the surplus earned by foreign agents is not usually included. For example, if the construction of a port is carried out with European funds, in its evaluation we should consider the benefits and costs of the agents of the European Union (or those based in the EU) affected by it, but not the surplus of shipping firms and other non-EU operators who could use it.

The social groups that matter in the evaluation of a project are generally all the affected groups without exception as, for example, occurs in the evaluation of a road that reduces the cost of travel to millions of users, including foreigners. By contrast, in infrastructure mainly used by foreign companies, such as, for example, a container transshipment port, it seems reasonable to exclude the surplus of foreign operators, accounting for the income as social benefits (less the costs) for port authorities and other national agents and operators.

3. DECISION CRITERIA

This section presents the decision criteria to approve or reject, select between mutually exclusive alternatives or choose from a range of projects within a limited budget. The fact that this section appears after the project definition, determination of the base case and analysis of relevant alternatives is purely for expository reasons. In fact, the criteria have been decided and publicly known before the project definition process.

3.1. Economic evaluation vs. financial evaluation

The evaluation of a transportation project helps make decisions about the project by comparing the benefits and costs generated over time. If these decisions are made from the point of view of society as a whole, the comparison must include all the social **benefits and social costs** of the agents affected by the project, even if some do not directly conduct transactions in the transport market. However, when decisions arise from the standpoint of who runs the project, it is only relevant to consider the **revenues and costs** generated by the project for them, especially if they also provide the funding.

It is important to remark that, as opposed to social benefits and costs, these revenues and costs are generally referred to ***private* benefits and costs**. However, this adjective should not be associated to the fact that the project is implemented by private companies. In fact, these revenues and project costs are also vital from the perspective of public finance because the more self-sustaining the project is, the lower the contribution from taxpayers.

In most transport projects, social benefits and costs are not limited to a mere accounting of revenues and costs. For example, when you want to quantify how much benefit a service of urban passenger transport generates to society, its benefits cannot be limited to gross income earned by those who supply the service, but must include the total valuation carried out by society, as measured by its total WTP, including users and nonusers (for example, those who can drive their private vehicles at higher speeds).

Similarly, when private costs are valued at the social opportunity cost, social costs are obtained by adding to the private costs all costs associated with externalities (e.g. air pollution) that are not normally considered explicitly by those who provide the services, whether public or private companies. In other cases (e.g. when there is high unemployment), the true opportunity cost of the resources used is lower than the market price used for the valuation of private costs, so the execution of the project makes the social costs lower than the private costs.

The evaluation of a transportation project can be approached from two different perspectives: **economic evaluation**, considering the benefits and costs the project generates for society as a whole, or **financial evaluation**, just focusing on the revenues and costs generated by the project.

In short, **economic evaluation** is performed by comparing the social costs and benefits of a transportation project, once homogenized temporarily through their **social net present value** (NPV_S). By contrast, the financial evaluation only compares the income and monetary costs associated with the project, calculating their **financial net present value** (NPV_F).

Both approaches address two different but highly interrelated questions. The economic evaluation attempts to provide an answer to whether **the project should be carried out** from the perspective of society as a whole and with reference to the project's contribution to social welfare. The financial evaluation is related to the project's viability and ability to generate income flows that will cover its costs, thereby implicitly wondering **is it possible to have private participation?** The answer to this second question is crucial to determine the degree of interest and the forms of participation of private actors involved in the project, whose decisions are assumed to be guided by the objective of maximum (private) benefit. However, as noted above, the financial evaluation is also crucial to know the possible implications of the project on public finance and the effect it might have on other projects being financed by the state. **The economic evaluation and the financial evaluation** can never be seen as sealed compartments, because both are linked through the pricing policy and the construction and operation of projects with private participation.

Finally, there is an important additional dimension that significantly influences both the private and social perspectives in the evaluation. This is the fact that **any decision on a transportation project must necessarily be addressed under conditions of uncertainty** about the possible outcome. Project evaluation should always be performed with the best information available, but even in the best case it is often insufficient because of our inability to fully predict the future in a context of bounded rationality.

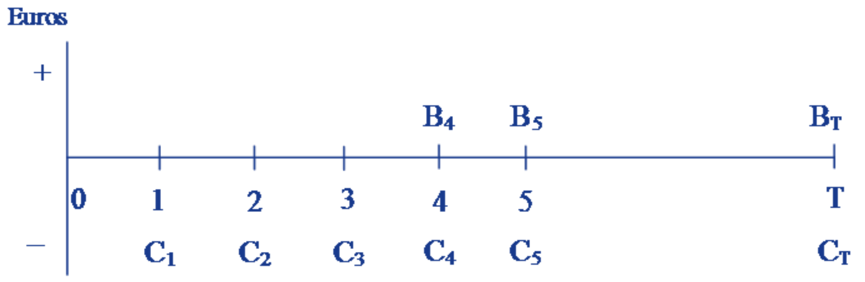
The evaluation of projects from the private perspective incorporates the risk discounted at the cost of adequate capital. According to the Capital Asset Pricing Model (CAPM) model, the capital cost of the project is the risk-free rate adjusted for the risk premium depending on how the project affects the systematic risk of a diverse portfolio of economic assets. By contrast, in the public sector it is generally considered that the government should behave as a risk neutral agent because the financial burden shared among millions of taxpayers makes the cost of risk approaching zero (in other words, the expected value is equal to the certainty equivalent). Still, the public decision-maker might find it useful to know the probabilities of the different values of *NPV* rather than only the expected *NPV*, either because the project has a cost that makes the taxpayers' contributions significant or because the decision-maker considers that a high probability of negative social *NPV* is an element to be read in conjunction with other features of the project.

The **uncertainty** associated with a project must be present from the beginning in the **tools used to support the decision criteria** that allow carrying out its evaluation. In addition to the expected NPV of the project, the decision-maker will know the different probabilities associated with positive and negative values.

3.2. Decision tools

From a formal point of view, when there is uncertainty any transportation project can be represented as a **stream of random benefits and costs** that are conducted along different points in time, consisting of elements that can be controlled and others that are totally unpredictable. Thus, let $t = 0$ denote the period in which intervention occurs in the transport market and $t = T$ the last period in which the intervention has an effect. The time profile of a project is graphically summarized in *Figure 3.1*, where the gap between social benefits and costs, and private costs and revenues are calculated for each project alternative and always compared with the base case.

Figure 3.1: **Time profile of a transport project**



As in most transport projects involving the construction or expansion of infrastructure, the figure shows that during the early years there are only costs (*construction period*) and that this difference is gradually offset from the start of the project (*operating period*). The net profit in each year in *Figure 3.1* can be regarded as the expected value given the limits of benefits and costs, and their associated probabilities.

There are two main **sources of uncertainty** associated with the evaluation of transportation projects:

a. The **uncertainty of the project** strictly linked to the fact that there are unpredictable contingencies whose occurrences affect the flow of benefits and costs. Thus, for example, it can occur that demand is lower than initially predicted (e.g. because of an economic crisis) or the *input* prices (e.g. oil, wages, etc.) grow at unexpected rates. This uncertainty can be either *internal* to the project (when constructing the infrastructure there are unexpected difficulties on the land that increase the cost of construction) or *external* to it (a general strike or a natural disaster). In both cases, this source of uncertainty is difficult to control.

b. **The uncertainty in the evaluation**, which is related to the information available about certain parameters required for the evaluation (value of time, elasticities or demand or cost parameters, etc.) and is present even if there is no uncertainty about the project.

Both types of uncertainty can be incorporated into the evaluation from the available information on the range of values and/or the probability distribution that can take those parameters. When this occurs, these probability distributions are translated into the benefits and costs, which are then transformed into random variables. If there is no more information than the maximum and minimum values, the less demanding distribution is the **uniform** (assigns the same probability of occurrence to each of the possible values). Sometimes we have some certainty about the most likely value, in which case the **triangular distribution** is a good choice. The **normal distribution** can be used if we know the mean and variance. In other cases, we can use asymmetric or truncated distributions, or if there are historical data, histograms that reflect the expected behavior of the corresponding variables.

Economic evaluation under uncertainty requires **modeling the behavior of the (random) variables** that determine the outcome of the project, and instead of getting a particular value of the NPV of the project, you get a probability distribution of it (a range of possible values and the probability that these values occur).

The Net Present Value

Although there are different tools that allow the comparison of flows (changes) in the benefits and costs (private and social) of a transportation project, the most widely used in CBA is the Net Present Value (*NPV*), which consists of simply discounting these flows to a common reference period (usually the beginning of the initial period t = 0).

In this way, formal expressions of the social and financial *NPV*, which correspond respectively to the realizations of benefits and costs of any project, for example the one depicted in *Figure 3.1*, would be given by:

$$NPV_S = \sum_{t=0}^{T} \frac{\Delta SW_t}{(1+i)^t} \qquad \textbf{(3.1)}$$

and

$$NPV_F = \sum_{t=0}^{T} \frac{\Delta PP_t}{(1+i)^t} \qquad \textbf{(3.2)}$$

where ΔSW_t represents the change in social welfare (social benefits less social costs) in each of the periods with respect to the base case, and ΔPP_t is the change in *private* profits (the difference between revenues and private costs) in each period *t*, and also in relation to the base case. The parameter *i* is the **discount rate**, which is usually assumed constant and equal for all periods.

The NPV summarizes in a single numerical value the flow of benefits and costs over the lifetime of the project, allowing a simple comparison of these benefits and costs for different points in time. Of course, when those flows of benefits and costs are random variables, the *NPV* is also a random variable, whose values correspond to each concrete realization of the project.

Through the NPV, the benefits and costs of a transportation project are homogenized and compared to a **reference point** determined by the evaluator, usually at the initial period $t = 0$. This comparison is interpersonal (the aggregation of the various agents involved in the project) and temporal (the aggregation of the results obtained in different times).

Interpersonal comparison

In general, the positive and negative effects of transport projects are distributed in the long run over society as a whole. However, in most cases a specific project affects specific social groups and geographic areas. This means that decisions taken on the majority of projects are influenced, inevitably, by the expected distribution of positive and negative effects. Decision-makers do not only care about the magnitude of benefits and costs, but also (and sometimes especially) about who wins and who loses with each project and the weight assigned to each of these social groups.

Although studying the implications of equity issues associated with the evaluation of transport projects requires a specific analysis (discussed in more detail in ***Appendix III***), it immediately highlights the difficulty of identifying the final winners and losers. For example, when investments made in a road network reduce travel time, this benefits road transport companies (whose costs decrease). However, it is possible that the competitive nature of this industry ends up transferring these benefits to the companies that produce the products transported and, depending on the degree of competitiveness in the product markets, to final consumers. This is not the only line of distribution of benefits because if there are any fixed factors such as land, the ultimate beneficiaries are the owners of the fixed factor.

The position of the evaluator in relation to this interpersonal comparison between groups and territories is incorporated in the choice of the tool used for the comparison of benefits and costs of the project. Thus, when calculating the NPV according to expression (**3.1**), i.e. an unweighted sum of all benefits and costs, we are implicitly using a valuation based on the so-called **criterion of potential compensation (or Kaldor-Hicks)** in which the same value is given to a monetary unit regardless of who receives it. If a project passes the criterion of potential compensation, the winners could compensate (at least hypothetically) the losers and still remain winners. This criterion might be reasonable when there are many projects that end up in the medium-term benefiting the whole population.

This approximation would mean that different social groups and/or territories whose benefits are being compared through the *NPV* have the same weight from the point of view of who conducts the evaluation. Therefore, we ignore not only the issue of equity, but also differences in individual welfare changes that occur with identical income increases if the individuals that receive them have initial allocations based on different incomes.

An evaluation that ignores distributional aspects can be reasonable if the redistributive effects of the project are not significant, difficult to identify or measure or even being possible to measure them it does not worth its cost. An additional argument against the use of distributional weights in the calculation of *NPV* is based on the idea that its use confuses and might lead to the manipulation of the figures reflecting the economic effects of the project. Finally, it can be argued that if many projects are carried out, in the long run most individuals will be ultimately benefited. In any case, the criterion of Kaldor-Hicks compensation is compatible with the government establishing real compensation measures (although incomplete) as it considers appropriate (e.g. compensation for expropriation).

> The main problems we face in considering the distributional effects are their identification and measurement. In general, the criterion that is adopted in the evaluation of projects is the potential compensation criterion.

Intertemporal comparison

Both the social *NPV* and financial *NPV* benefits and costs of the project are expressed in monetary units for different time periods. For this reason, when the monetary expression of cost and benefit flows change as a result of inflation, the first question that might arise with regard to the intertemporal comparison of benefits and costs is whether to perform the project evaluation in nominal terms or real terms.

Given that the purpose of evaluation is simply to compare changes in social (or private) welfare, the evolution of the nominal value is irrelevant: what matters is the use of resources and the generation of benefits associated with the project. It is, therefore, possible to ignore the purely monetary changes that do not affect the real terms over the life of the project.

However, even if it is indifferent to work with current or constant values, it can sometimes be advisable to work with data expressed in **current monetary units** because in addition to the fact that it can be easier (data are generally expressed in current terms), the financial project's dimension demands it, for example, in infrastructure where users pay for the use (tolls or fees) and where the private sector is involved as a manager. Whatever the cause for which the series are used in real or nominal terms, the evaluation must be consistent. If the data are expressed in nominal monetary units each year, you have to use a nominal discount rate (i_n). If the data are expressed in monetary units of the base year, the discount rate should be the real one (i). If φ represents the rate of inflation, both expressions would be related by:

$$i = \frac{i_n - \varphi}{(1+\varphi)} \; .$$

The consideration of inflation does not affect the results of the economic evaluation of a project. The evaluation can be performed both in nominal and real terms, adjusting in each case the value of all monetary magnitudes involved and the rate of discount.

A second issue in relation to the intertemporal comparison of benefits and costs has to do with **the choice of discount rate**, whose function is to reflect the degree of preference for the present versus the future that is adopted in the evaluation. The decision is not neutral, because depending on the temporal structure of the project, the value of the discount rate influences in one way or another the decision on it. Thus, when most costs occur early in the project and the benefits are obtained at the end, higher discount rates produce lower values of *NPV*. On the contrary, the acceptance of projects where the main costs are incurred at the end will be favored by higher discount rates.

This form of temporal homogeneity, through exponential discount, is appropriate for projects affecting the same individuals at different periods of time during a reasonable time horizon (usually 20 or 30 years depending on the project). Its usefulness is more questionable when transport projects (e.g. the construction of some infrastructure or policies affecting the stock of natural resources) have effects that affect the welfare of future generations.

Alternatively, one could argue that economic growth allows future generations to be richer than those who have to sacrifice present consumption today, thereby justifying the exponential discount (if damages were not irreversible).[5] This question is again related to issues of equity, so it is addressed in ***Appendix III***.

Whatever the discount rate used, it is common to place the flow of costs and benefits at the end of each period analyzed (usually "years") but in reality the benefits of all transportation projects occur continuously. This convention stems from the fact that, generally, information is obtained at the end of the year, although the analyst could decide to put the data for the calculation of *NPV*, for example, at the middle of the year. If the benefits and costs start from the beginning of the year, it might be reasonable to place an average of all flows in the middle of the year, which would amount to treating them as occurring daily or almost continuously, but applying a discount rate across the year. In most projects, this does not significantly change the outcome of the evaluation.

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[5] For example, it is generally considered that in the case of certain benefits (such as those resulting from the reduction in deaths or injuries from traffic accidents) the discount rate need not be the same as that used to discount other benefits.

The choice of social discount rate

In the financial evaluation of a transportation project, the discount rate (private) most commonly used matches the current interest rate on the market. However, for the choice of social discount rate in economic evaluation there are, in general, three possibilities:

- **The market interest rate**,
- **the marginal rate of time preference**, or
- **the marginal rate of capital productivity**.

These three rates coincide when capital markets are *perfect*, i.e. when there are no restrictions on financial markets, taxes or other distortions on production or consumption. Unfortunately, this is not true in reality: for instance, in a capital market with taxes, the marginal rate of productivity of capital is greater than the interest rate because of the lower profitability of investment since taxes must be paid on dividends; similarly, the marginal rate of time preference is smaller than the interest rate, since agents save with remunerations net of taxes below that rate.

Therefore, we should distinguish between two situations: if the public sector competes with the private sector for the implementation of a project, the discount rate used should be the marginal rate of capital productivity. But if, on the contrary, we evaluate projects within the public sector, obtaining funds from various sources, we can act in two ways:

a. Use a weighted average of the marginal rate of time preference and the marginal rate of productivity of capital, depending on the source of funds used in the project.

b. Discount the flows of benefits and costs using as the social discount rate the marginal rate of time preference, but having previously converted the net benefits in consumption flows through a **shadow price** of capital. This method requires more information because it needs to know the destination of the benefits achieved over the life of the project.

> The **social discount rate** used in the economic evaluation of a project should reflect the **opportunity cost** of the resources used in this project over time.

In practice, the discount rate is determined by the Ministry of Economy. In general, a good option is to use the marginal social rate of time preference which is used in the manuals of the European Commission, France and the UK.

3.3. Decision-making

After the homogenization and comparison of the flows of benefits and costs of a transportation project, the economic evaluation process can finally establish criteria for making decisions based on them. Among other factors, these decisions are often conditioned by two factors: the number of alternatives considered by the evaluator and the way in which they decide to internalize the uncertainty surrounding the evaluation process.

Types of decision and decision-making procedures

In projects involving the economic evaluation of a single alternative *ex ante*, the only relevant decision is to **accept or reject** the project, i.e. whether the project – under the stated circumstances – must be undertaken or not by society. Even in the case where the NPV of the project is positive, the problem of the optimal timing of its implementation remains, an issue discussed at the end of this section.

In other cases, the decision to be made involves the **comparison of two or more projects** competing for the same funding.

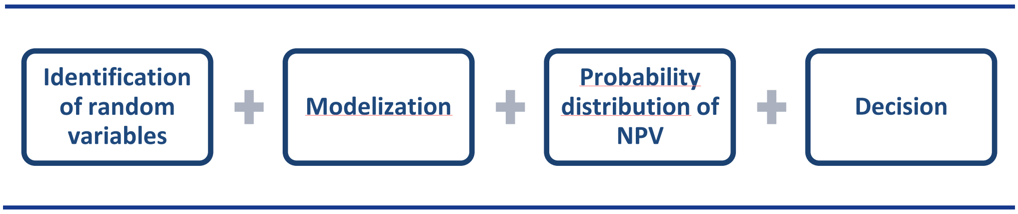
Although the type of decision to be taken depends on the circumstances of the evaluation process and the characteristics of the project, it is the task of the evaluator to determine explicitly **how to internalize the uncertainty** associated with the evaluation within the decision criteria. In general, there are three possibilities:

1. **Completely ignore the existence of uncertainty**. In this case, the evaluator should consider *decision criteria without uncertainty* based on the deterministic values of social *NPV* and financial *NPV* that allow them to make the required decisions. This approach – traditional in CBA – can be reasonable in projects where the magnitude of uncertainty is low, the risk of error is minimal or it has a low cost to the evaluator.

2. **Incorporate uncertainty through sensitivity analysis**. This is an intermediate option in which the decision is based on deterministic criteria, but considering that the evaluation results could vary by modifying certain parameters of it. The evaluator repeats the analysis with the different possible values of these parameters (even defending alternative scenarios where multiple parameters vary), considering only partial changes in them. Although the information thereby obtained is richer, it could lead to a false sense of certainty, since the procedure ignores the possibility that many of the changes happen simultaneously and in a correlated way.
3. **Incorporate uncertainty into the tools of decision-making**. In this case, the evaluator should develop *decision criteria under uncertainty*. This third possibility is the most comprehensive but also requires more information. The idea is to consider, as presented,

that social *NPV* and financial *NPV* consist of probability distributions, so the decision should be based on the properties of such distributions.

This incorporation of uncertainty into decision tools in the evaluation of transport projects is made through four stages:



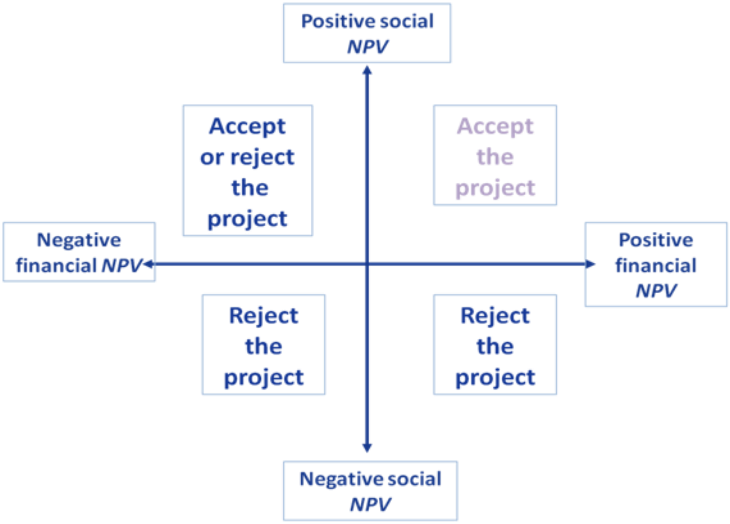
1. First, it is necessary to **identify the variables** in which the evaluator places the uncertainty (whether internal to the project or external to it). The list can be comprehensive: rates of growth of demand, cost values, model parameters, etc.
2. Then, the evaluator must – with the best information available and after consultation with specialists and experts – determine the extreme values of these variables (maximum, minimum) and characterize the extent to which their probability distributions (mean, mode, variance) are possible. An important additional element is to determine the degree of correlation between variables, which must be based on technical and economic criteria (for example, the correlation between income and traffic). If you choose a value for each variable regardless of the value that was chosen for the others, this can lead to inconsistent results. When some variables vary together, that relationship should always be included in the model to avoid unlikely scenarios.
3. The third step is to calculate the probability distribution of *NPV*, by the extraction of a sufficiently large number of possible values of each of the random variables comprising it and the subsequent implementation of the expressions (**3.1**) and (**3.2**), adequately developed to include the probability distributions.
4. Finally, upon completion of the above steps, you can proceed to take the decision.

Decision criteria without uncertainty

Figure 3.2 shows the simplest case of **accepting or rejecting** a project.

- **Accept the project (NPV_S>0, NPV_F>0)**. Any transportation project that will generate a positive social *NPV* and a positive financial *NPV* should be undertaken, as it not only increases social welfare, but also generates sufficient funds to pay for possible private sector involvement in the project and might not even require additional funds from the state.

Figure 3.2: **Decision criteria without uncertainty**



- **Reject the project ($NPV_S<0$)**. A transportation project whose social *NPV* is negative should not be done under the existent circumstances because the present value of the social benefits is not sufficient to offset the discounted sum of social costs, regardless of the sign of the financial *NPV*.
- **Accept or reject depending on the existence of budget constraints ($NPV_S>0$, $NPV_F<0$)**. When a project is socially desirable (positive social *NPV*) but does not generate sufficient funds to attract private sector investment (negative financial *NPV*), society must carry out the project only if there are no relevant budget restrictions from the government. If there are such restrictions, society might have to reject this type of project.

When the decision to be made is to **choose between different projects**, the criteria used should be based on the above principles. Society should focus on projects with higher social values and always delay or reject those whose contributions to social welfare is lower, taking into account the existence of budget constraints.

The main **advantage** of using criteria for decision-making without uncertainty lies in its ease of interpretation and the limited cost of calculation. The **disadvantage** is that the possibility of taking a wrong decision is higher. These two elements must always be weighed up by the decision-maker. One way to complement this process that is commonly used in conventional CBA techniques is simply to incorporate a sensitivity analysis (or scenarios) to the main values of the model, seeing how much and how they change the values of *NPV* when changing certain parameter(s).

Decision-making in the absence of uncertainty simply determines **what values of social *NPV* and financial *NPV*** (deterministically defined) should lead to **accept or reject** a transportation project or **choose** from several available projects.

Decision criteria under uncertainty

When uncertainty is incorporated into the evaluation, using risk analysis in addition to the expected *NPV*, the decision-maker has the probability distribution of *NPV*. This information is not that useful for the often risk-averse private sector because the expected *NPV* does not consider as a certainty equivalent to take the decision to invest. Furthermore, through risk diversification it is possible to bring the certainty equivalent closer to the expected value. In the case of CBA, a prior question is whether the public sector must act as risk neutral or not.

The most general position, based on the **Arrow-Lind Theorem**, consists not so much of the diversification of risk based on the realization of many projects that by the law of large numbers end up making the expected *NPV* match the actual *NPV* obtained from the public sector, but of risk-sharing between a high number of people who make the cost of risk approach zero.

The idea is as follows. By sharing the risk of a public investment project among a large number of taxpayers, one can argue that even in the case of individual projects the cost of risk tends towards zero since each taxpayer provides a small amount to finance the project. In these circumstances, it makes sense to work with expected values.

The probability distributions produced by the evaluation that incorporates the risk analysis provide the expected *NPV* and, therefore, the information necessary for the public sector to act as risk neutral. However, the risk analysis provides much more information. Besides the expected *NPV*, the decision-maker now has a range of possible NPVs and their corresponding probabilities. That is, we do not only know that the expected *NPV* is, for example, 100 million Euros, but also that the likelihood that once completed the project the *NPV* is negative by 30 per cent.

There could be at least two reasons why the decision-maker is interested in using this information. The first is that many transport projects represent an investment of such magnitude that the distribution of costs between the taxpayers affected makes those individual contributions significant. In these cases, the Arrow-Lind Theorem is not satisfied, so it is necessary to consider the cost of risk. The second is that the decision-maker is risk averse and thereby interested in the probabilities associated with different possible outcomes.

Decision-making under uncertainty requires explicitly considering its effect on the possible values of *NPV*, which also becomes a random variable. Now, the decision-maker knows the expected *NPV* and the different values that can be achieved with their probability of occurrence.

In any case, let us consider again these decisions distinguishing some possibilities, among others, that can arise.

Accept or reject a project (no budget constraint)

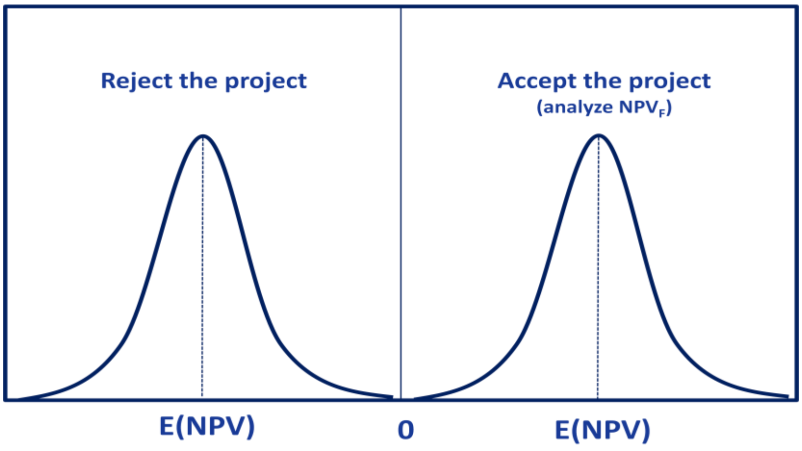
In principle, when the probability distribution of the social *NPV* presents no positive values, the decision criterion is identical to that encountered in the case of a deterministic evaluation in which $NPV_S<0$; therefore, the project should be rejected. On the contrary, if all the values that the probability distribution of the social *NPV* takes are positive, then the project should be accepted. When this distribution implies positive and negative values, the reference should be the expected value, accepting projects where:

$$E(NPV_S) \geq 0 \,,$$

where $E(NPV_S)$ denotes the NPV_S expected value.

This includes the two previous extreme cases. This approach is appropriate in cases where there are no budgetary constraints and the decision-maker is risk neutral.

Figure 3.3: **Accept or reject a project**

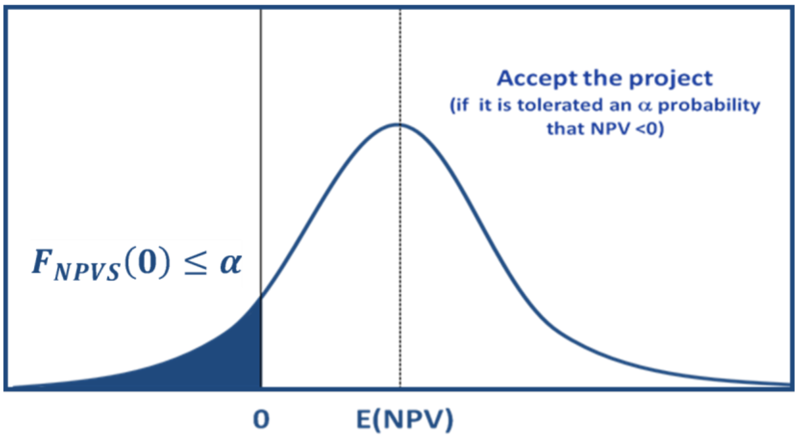


However, when the risk associated with the probability of negative values of social *NPV* is relevant to the decision-maker – for any of the reasons discussed above – they must incorporate in the decision all the information provided by the probability distribution, and the decision to accept or not the project then depends on the threshold of risk that they are willing to accept. That threshold can be measured, for example, in terms of the tolerance of negative results (a probability α). Thus, F_{NPVS} represents the cumulative probability function of social *NPV* (distribution function) and $F_{NPVS}(0)$ the probability that social *NPV* is negative. Therefore, the project should be accepted only if:

$$F_{NPVS}(0) \le \alpha \,,$$

as reflected in Figure 3.4 where it is considered that the critical value α must be set exogenously and before carrying out the evaluation.

Figure 3.4: ***NPV*** **distribution function**



In cases where the decision-maker is not only interested in the probability of losses but also in the possible *magnitude* of them, the two criteria just presented might not be enough and should be supplemented with an additional measure that, in relative terms, indicates the importance of obtaining negative values of social *NPV*.[6]

Accept or reject a project (budget constraints)

When there are budgetary constraints all the above criteria should be subject to obtaining a (expected) financial *NPV* positive or at a tolerable level of losses determined by the government.

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[6] Although there are other alternatives, an option would be to calculate the absolute value of the ratio:

$$\frac{E(NPV_S)}{E(NPV_S \mid NPV_S \le 0)}$$

The denominator of this ratio contains the expected value of the loss distribution. A higher value of this ratio would favor the project, being rejected the smaller the above ratio.

In cases where the financial result is unfeasible, together with the possibility of rejecting the project, it should be considered a possibility to modify the income and private costs, for example through pricing policies, to increase the probability of higher financial *NPV* values, even at the cost of reducing social *NPV* (as long as it is not negative).

Choose between two (or more) projects

When the decision that arises is to compare two (or more) alternative projects, the decision should be formulated in terms of the different 'filters' that allow us to dismiss the worst projects. In the case that there were no budgetary constraints, these filters would be determined by the above criteria, so that:

1. Firstly, we have to rule out those projects that are not positive (in terms of expected social *NPV*).
2. Thereafter, we should discard the projects that even obtaining $E(NPV_S)>0$ have a cumulative probability of incurring negative social benefits higher than a probability threshold α set by the decision-maker.
3. Finally, we would rule out projects that meet the second requirement but present very high values of expected social losses in the event that the project has negative values of social *NPV*.

If there were budgetary constraints, we should add the two additional criteria previously established for the case of accept/reject a project:

4. Discard the projects that would generate a NPV_F lower than the established threshold.
5. Discard also those with a positive expected NPV_{F} but whose probability of losses was not assumed by the decision-maker.

Once passed all the filters in the event that there is no budget constraint (filters 1, 2 and 3) or if there is a budget constraint (filters 1, 2, 3, 4 and 5) we will select the project with higher expected social *NPV*.

The decision to delay a project

When the *NPV* of a project under evaluation is positive, we know that it is socially desirable; however, saying that the project is profitable in the base year is not to say that we should start it in that year. It is possible that the *NPV* is greater by delaying the start of the project.

Even with positive social and financial *NPV*s, it can be socially profitable to wait, because by waiting we might improve the outcome since, for instance, profits are growing and in the early years they are relatively low, or maybe because of the disclosure of information not available in the present about demand or technology that changes the expected profitability of the project in year zero. Let us consider the two possibilities.

When additional information is not revealed by the fact of waiting

Sometimes, the comparison between projects consists of assessing whether it is more profitable to start today or wait until next year. There can be multiple reasons that make it profitable to postpone the project, when this is technically feasible. Perhaps the demand is growing and the social benefit derived from the demand for the first year is not worth the opportunity cost of funds to invest. Suppose that the project involves an initial investment equal to I and an annual net profit B_t. It is profitable to delay a year if $\mathbf{B_1 < i \cdot I}$, in which case the benefit of delaying the project a year is less than the return on investment from the best available alternative.

When delaying the project reveals additional information

When investment is irreversible, when there is uncertainty about the social benefits generated by the project during its lifetime and when it is possible to postpone the start of the project, the alternative of delaying its execution cannot be ignored without the standard *NPV* being damaged as a decision criterion.

If delaying the project reveals valuable information about net annual profits, the monetary value of that information is lost when the investment is made in the present. Under these conditions of irreversibility, uncertainty and the possibility of delay, there is an opportunity cost of making the investment in the present. By investing today, we will lose the economic value of such information that is revealed by waiting and, therefore, it should be included as a cost in the calculation of *NPV*. The rule of *NPV*>0 to approve a project remains valid provided that the costs include the opportunity cost of investing today when postponing the investment reveals information with economic value.

The above reasoning for calculating the cost of not waiting can be presented by choosing between two mutually exclusive projects: one consisting of investing today and another delaying investment. We alternatively calculate the *NPV* of both projects and choose the higher one.

4. METHODS OF CALCULATION OF CHANGES IN SOCIAL WELFARE

Every transport market in equilibrium can be interpreted in two different but equivalent ways. On the one hand, it can be seen as a specific allocation of productive resources associated with the economic activity carried out by the social partners that participate in the market – *producers, users, taxpayers and the rest of society* – providing society with concrete results, in terms of price, quantity and quality of transport. On the other hand, the distribution of these results always involves certain gains or losses for each group of agents, which can be measured in terms of net surpluses for each of them. Since transportation projects alter the results achieved in equilibrium in transport markets and also alter the distribution between the agents involved, the calculation of changes in social welfare caused by a transportation project can be addressed from these two perspectives.

> Measuring **changes in social welfare** caused by a transportation project requires the consideration of the effects of the project on the equilibrium of the markets affected by it, either by examining the changes in **surpluses** or by examining the change in the **allocation of resources and the WTP**.

The first perspective is intended to measure the **net changes in the use of the resources of production provided by society and in the users' WTP** that occur as a result of the implementation of a transportation project. It is based on comparing the equilibria *with* and *without* project and quantifying the change in productive resources and WTP as a result of implementing the project, ignoring transfers that might occur between the agents involved.

By contrast, the second perspective is based on estimating **changes in the surpluses of the different agents** when moving from the equilibrium with project to the equilibrium without project. This section analyzes in detail both approaches, showing that they are equivalent procedures that lead to the same result and whose choice will depend largely on the available information.

4.1. The productive resources approach

The availability of data often leads us to discuss projects in terms of changes in productive resources, which are necessary to understand what role each of them plays. Thus, from the point of view of society as a whole, the production of infrastructure and services in any transport market requires the use of three kinds of productive resources, distinguishing them according to their origins:

- Those provided by the **producers** to the production function (capital (K), labor (L), mobile equipment (E), energy and spare parts (R), including in capital the use of infrastructure in the provision of services and all other assets except for vehicles),

- travel time as a resource provided by **users**, and
- finally, all resources – natural or not – contributed by the **rest of society**.

Social costs of transport

The use of these factors represents a social opportunity cost because of the resignation to apply the same in other alternative uses.

Therefore, depending on who provides the resources (and bears, therefore, that cost) we can distinguish among the producers' costs (C_P), users' costs (C_U) and the costs of the rest of society (C_{RS}). The sum of these three items provides the social cost (C_S) of any transport activity:

$$C_S = C_P + C_U + C_{RS}, \qquad \textbf{(4.1)}$$

which represents the cost generated to society as a whole by the actual allocation of resources designed for a certain infrastructure and transport services. In more intuitive terms, the social cost represents all other goods and services that society fails to receive because of the allocation of the inputs and resources to the project. Let us analyze each of its components in more detail.

Producers' costs

From an integrated perspective, the producers' costs in a transport market correspond with the use of inputs provided by the companies carrying out the provision of transport infrastructure and services in a given market.

Thus, the main items of costs would be associated to capital (including infrastructure), labor costs, costs associated with mobile equipment and the costs of energy and spare parts:

$$C_P = p_K K + p_L L + p_E E + p_R R, \qquad \textbf{(4.2)}$$

where p_K, p_L, p_E and p_R represent the corresponding unit prices for each *input* valued at their social opportunity cost.

If we approach this function from the point of view of a short-term economic analysis in which any of the factors can be fixed, (usually K, E or both), then the maximum capacities of the infrastructure or transport services are implicitly set as ($\overline{q}_I$, $\overline{q}_S$), which allows us to reformulate the cost function of the producer:

$$C(\overline{q}_I;\overline{q}_S;q) = a\overline{q}_I + b\overline{q}_S + cq = F + cq, \qquad \textbf{(4.3)}$$

where q is the actual utilization of transport capacity, determined by demand, and a, b and c are the respective unit costs (not necessarily constant) associated with a unit increase in infrastructure capacity such as an increase in a unit of capacity of passenger vehicles or in attending an additional traveler. In the long run, all costs in (4.3) are variable costs, whereas in the short run any of the two initial addends (or both) is a fixed cost (F) since it does not vary with q.

Users' costs

Users provide the travel time (τ) for the provision of transport services and their cost is determined by the *disutility* usually generated to individuals by travel time. This disutility has a monetary value per unit time (v), because users would be willing to pay if the conditions of travel improve and they (or their goods) arrive at their destinations in less time. Therefore, $v\tau$ represents the opportunity cost of that time. In other cases, it is not possible to establish such a direct relationship, and it is appropriate to consider separately the valuation of the discomfort and other elements of disutility that can be expressed as θ).[7]

In this way, and assuming for simplicity that for the average individual v is the monetary value of time and θ is the monetary value attributed to the disutility of services, the total cost borne by users (q) is:

$$C_U = C_U(q,\tau) = (v\tau + \theta)q, \qquad \textbf{(4.4)}$$

where the unit cost (or average) per user is equal to:

$$c_U = \frac{C_U}{q} = v\tau + \theta. \qquad \textbf{(4.5)}$$

Costs for the rest of society

The determination of costs for the rest of society associated with the production of transport infrastructure and services requires assessing in a broad sense the opportunity cost of the natural resources contributed to this production by agents external to the transport activity, i.e. those who are neither producers nor direct users of it. We can use a suitable valuation function $\varepsilon(\cdot)$ to quantify these:

$$C_{RS} = \varepsilon(N)\,. \qquad \textbf{(4.6)}$$

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[7] The parameter θ is a measure of disutility that can be interpreted as the "monetary value attributed by users to the disutility of transport services." It can include, in addition to discomfort, aspects such as accident risk assessment associated with using a particular transport mode or, in the case of goods, issues concerning the reliability of deliveries, risk of breakage or theft, etc. Sometimes you just include it in the value of time.

In general, when *N* is interpreted as "natural resources" this expression would assess the damage caused by pollution, visual intrusion, noise, barrier effects, residues and any other impacts on the environment.[8]

Identifying and measuring the costs for the rest of society is not always easy, particularly in regards to their relationships with *externalities*. The term "externality" (or external cost) is commonly used to refer to all the effects (both positive and negative) caused by transport activity to those not directly involved in it. This definition does not create excessive difficulties with regard to the environmental damage of transport: it refers to damages caused to third parties ("rest of society"), but they also affect the group of producers and users of transport on the market in the case that are internalized as with Pigouvian taxes. In any case, we must avoid double-counting.

With regards to accidents, part of the cost is borne by transport users and producers, whereas another part is borne by the rest of society. Users internalize the cost that corresponds to them, for example, by paying insurance or assessing the risk of an accident as an additional dimension of disutility (in θ), whereas actions by the producers to reduce this risk are reflected in the producers' costs. The remaining costs (accidents involving pedestrians, for example) are computed in the "rest of society" costs (***Appendix III***).

In relation to congestion, from the point of view of CBA, the fundamental distinction is whether it occurs within the primary or secondary market. If the project involves a reduction of congestion in the primary market, the effect is measured in the new travel time for users *with* project in contrast to the situation *without* project within the transportation market. When the change of equilibrium in the primary market affects a secondary market in which there is congestion, the effect receives the same treatment as any other indirect effect, and should be included or not in the computation of the benefits and costs of the project depending on whether there is a difference between price and marginal cost in that market (congestion optimal rate in this case).

Users' willingness to pay

In general, the main benefits of a transportation project are reductions in the generalized prices of existing users (time savings, increased quality, etc.) and the WTP of new users. Ideally, in both cases we should calculate the impact of the changes produced by the project on welfare or the utility of individuals; however, utility is immeasurable, so an alternative used by economists is applying a monetary valuation of these benefits.

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[8] If *N* is treated as other resources provided by society in the production of transport infrastructure and services – particularly public services such as police or the public health system – the expression (**4.6**) reflects the opportunity cost of these resources that is attributable to transport activity, although these costs can either be included in the taxpayer group or the public producers group whose negative net balance will eventually end up in the contributors' balance. What is important is accounting for all the resources used or saved with the project and avoid double-counting.

Both for the time saved in the existing traffic and the social value of new traffic (generated or diverted from other modes), we use the concept of **WTP** as a monetary proxy of changes in individual welfare. These monetary measures of actual changes in utility are comparable only if a monetary unit has the same effect on social welfare regardless of who the individuals are and their levels of income. Henceforth, we assume that a monetary unit has the same effect on welfare regardless of the beneficiary.[9]

The foundations of WTP are settled in the **theory of consumer behavior**, particularly reflected in the concept of **compensating variation and equivalent variation** from which we obtain the transport demand resulting from a rational choice process in which a user (passenger or owner of freight) choose the amount of transport they want to consume taking into account the total *price* to pay for it. Thus, the demand for transport (e.g. in terms of daily trips on a particular mode of transport) is inversely related to the **generalized price** of each trip g, where g can be defined as:

$$g = p + v\tau + \theta, \tag{4.7}$$

where p is the amount paid by the user for every trip to a carrier in the form of a ticket, toll, freight, etc. This amount p is not part of the users' costs defined in (**4.5**) from the perspective of social cost excluding income transfers, since it is not a resource contributed by society in the production of transport but a mere transfer of money that is not counted under the resource approach adopted in this section.

As can be seen, the above expression refers to the generalized price on somebody else's account. In the case of transport on its own, where the user is also the producer, the price also includes the cost (average per travel) of operation and maintenance of the vehicle (z), adding if necessary, the other costs incurred by the user/producer to provide the service to themselves (e.g. tolls, p). We could also include in (**4.7**) taxes and unitary subsidies (denoted by ζ), which affect the generalized price, so the above expression would eventually be extended to:

$$g = p + z + \zeta + v\tau + \theta. \tag{4.8}$$

The (derived) demand function of transport $g(q)$ shown in *Figure 4.1* allows us to analyze in more detail the real value that users attach to the quantity of transport demanded. Initially, when the generalized price is g^0, the number of trips that would take place, for example, annually in a transport market is determined by q^0. This would mean that g^0 is precisely the maximum (generalized) price that the last user is willing to pay for the travel q^0, and so every one of the trips would be between 0 and q^0 if we measure the distance between a horizontal axis and the curve of demand. Therefore, the demand function reflects, from left to right, a sort of decreasing individual

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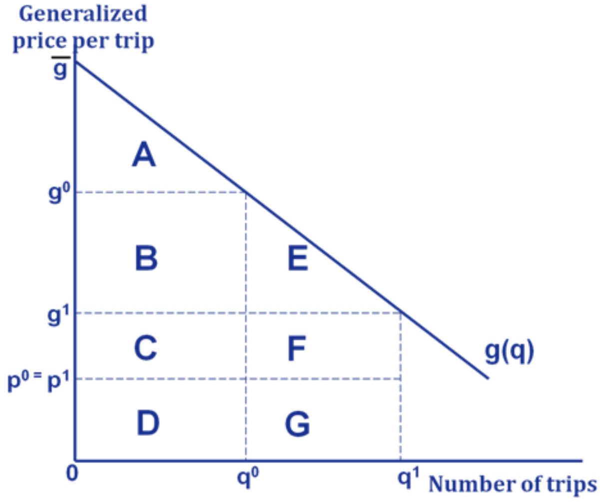
[9] The weights for reasons of equity (social marginal utility of income) include both the effect on the individual utility of increased income (marginal utility of income) and the effect of the change in individual utility on social welfare (social marginal utility).

assessment of transport, ensuring that the social value of q^0 travels or **users' WTP** for these trips is equal to the total area located below the function $g(q)$, that is, the sum **A + B + C + D**.

Figure 4.1: **Generalized price and willingness to pay**



A common simplification in this analysis is to consider that the monetary value attributed to the quality of services (θ), which is part of the (unit) users' costs defined in (**4.5**), is already included in the monetary value of travel time (v) and does not vary with the project ($v = v^0 = v^1$), so that the user cost can be simplified to $c_U = v\tau$. In Figure 4.1, we also assume for simplicity that $p^0 = p^1$, and that $z = \zeta = 0$. Thus, the vertical distance between g^0 and p^0 is equal to $v\tau^0$ according to (**4.8**), and the area **B + C** (i.e. $v\tau^0 q^0$) represents the total monetary value of travel time spent by users in this market before the intervention.

However, the definition of a transport project as a public action that alters the equilibrium initially reached in transport markets means that the calculation of WTP in absolute terms, as presented, is unnecessary. On the contrary, we only need the **change in the resources provided by the users and the change in WTP** caused by the addition of new users as a result of the project, which involves comparing a new equilibrium (g^1, q^1) with the initial equilibrium (g^0, q^0).[10]

Therefore, in *Figure 4.1,* it is considered that the only effect of the transportation project is a decrease in travel time ($\tau^1 < \tau^0$), leading to a new equilibrium where the number of daily trips increases to q^1, with $g^1 < g^0$. According to the above analysis, the total WTP for this number of trips is again equal to the area below the demand function between 0 and q^1, and the saving in resources is equal to area **B**, to which we must add the change in the total WTP for the

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[10] The decision on whether a profit is a change in the resources or in the willingness to pay is somewhat arbitrary. For example, a reduction of time in the existing traffic is considered in the manual as a resource saving, but it could also be seen as an increased willingness to pay for existing users. The important thing is to be consistent, and do not incur in doublecounting.

incorporation of new users (area **E + F + G**). The gross **monetary benefit** attached by users to the project is given by the area **B + E + F + G**.

Determining a change in social welfare

Measuring the change in social welfare (ΔSW) that occurs as a result of the implementation of a transportation project is to determine what resources (of those currently provided) will be saved by society as a result of this project, to determine what new productive resources are necessary to provide, to value these resources at their *social* opportunity cost and to add the social value of new traffic generated and, where appropriate, the indirect effects and other additional economic impacts.

With regard to the former and in aggregate terms, the value of the resources saved by society can be approximated from the difference between the social cost of transport activity *with* and *without* project. As defined in (**4.1**), this cost (C_S) includes the producers' costs, users' costs and external costs, together defined as the value of all the resources provided by each one to production.

Thus, the saving of resources to be counted for calculating the change in welfare that occurs as a result of a transportation project would include three elements:

1. The monetary value of the net use of the productive resources provided by the producers (public or private), as measured by changes in their costs ($C^0 - C^1$) where C^1 are the costs *with* project (including costs of investment) and C^0 the costs *without* project, valued both as a *social* opportunity cost, not represented in *Figure 4.1*.
2. The monetary value of saving the time of initial users, ($v\tau^0 - v\tau^1)q^0$ (also including possible improvements in quality within v) represented by the area **B** in *Figure 4.1*.
3. The monetary value of the change in resources provided by the rest of society. This includes issues such as the monetary valuation of the change in the generally negative externalities caused by the project. These effects are not necessarily proportional to the quantity produced, so it could be denoted by ($E^1 - E^0$), thereby capturing the change with project with respect to the externalities without project.

On the other hand, in addition to saving resources for the q^0 initial users (equivalent to the area **B**), decreasing the generalized price from g^0 to g^1 in *Figure 4.1* produces an increase in daily travel demand equal to $q^1 - q^0$. Since these are new journeys made in this market as a result of the project, they should be incorporated into the measurement of changes in social welfare.[11]

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[11] 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.

Therefore, we should add the **WTP of new users**, formally defined as the sum of the areas **E + F + G**:

$$\frac{1}{2}(g^0 + g^1)(q^1 - q^0)\ ,$$

but resources from new users must be subtracted. In this case, this is the value of time spent by them (area **F**): $v\tau^1(q^1 - q^0)$.

The sum of the above elements summarizes all the direct effects of the project, i.e. those that take place through changes in the equilibrium in the transport market on which the intervention takes place (market *j*).

Indirect effects are those induced by the project beyond the primary market. They are the changes that occur in the rest of the economy, including other transport markets on which the project does not act directly but that are affected by the change that occurs in the market directly affected by the project (these are the so-called intermodal effects). In general, it can be argued – and this significantly simplifies the evaluation – that the indirect effects can be ignored provided, in the markets where they occur, that the marginal social benefit equals the marginal social cost. When this does not happen, the indirect effect is the difference between the marginal social benefit and marginal social cost (expressed as a unitary distortion D_i) multiplied by the change in the quantity produced, as stated in the following expression:

$$\sum_{i \neq j} D_i (q_i^1 - q_i^0)\ ,$$

where the subscript *i* refers to all markets except the primary transport market (*j*).

Within the impact of the projects that reduce the cost of transport are, as already discussed, the so-called “wider economic benefits.” Although there are these additional economic effects, they have not been translated into clear criteria for the practice of the economic evaluation of projects. In fact, the risk of double-counting is so high that it is reasonable to exclude additional benefits in small projects focusing on the effort of the outcomes, investing resources for specific studies only in the case of large investment projects.

Finally, rearranging all the previous expressions, the **change in the annual social welfare** associated with a transportation project constructed **under the approach of resources** would be given by:

$$\begin{aligned}&(v^0\tau^0 - v^1\tau^1)q^0 + \frac{1}{2}(g^0 + g^1)(q^1 - q^0) - v^1\tau^1(q^1 - q^0) + \\ &-(C^1 - C^0) - (\mathrm{E}^1 - \mathrm{E}^0) + \sum_{i \neq j} D_i (q_i^1 - q_i^0)\end{aligned}$$

This expression corresponds to the comparison of the corresponding equilibria with and without project for one of the periods during which the project has effects, as was analyzed in *Figure 2.1*, in addition to the indirect effects on other markets.

More generally, for a project whose effects take place between periods $t = 0$ and $t = T$, the total change in social welfare would be:

$$\Delta SW = \sum_{t=0}^{T} \delta^t \Big[\left(v_t^0 \tau_t^0 - v_t^1 \tau_t^1\right) q_t^0 + \frac{1}{2}\left(g_t^0 + g_t^1\right)\left(q_t^1 - q_t^0\right) - v_t^1 \tau_t^1 \left(q_t^1 - q_t^0\right) + \\ -(C^1 - C^0) - (\mathrm{E}^1 - \mathrm{E}^0) + \sum_{i \neq j} D_{it}\left(q_{it}^1 - q_{it}^0\right) \Big], \qquad \textbf{(4.9)}$$

where δ^t represents the discount factor.

4.2. The Social Surplus approach

In contrast to the resources approach described so far, an alternative way of measuring costs and benefits is to calculate the change in the surplus of the different social actors as a result of the project. The change in the surpluses approach allows us to know who wins and who loses with a project, which can be essential to anticipate the degree of acceptance or rejection, to make some considerations from the point of view of equity and also to finance the project. In this case, payments or transfers made among the agents are relevant because they determine the final size of the income received by each of them.

The social surplus (SS) that occur in any market are divided among the four groups above:

$$SS = CS + PS + GS + RSS, \qquad \textbf{(4.10)}$$

so that it is composed of *users' surplus* (CS), *producers' surplus* (PS), the *surplus of the taxpayers* (GS) and the surplus we have called "rest of society surplus" (RSS). Let us analyze each of these elements in more detail.

Users' surplus

The surplus of the users is a monetary measure of welfare change in this social group that is related to WTP. Formally, it is defined as the difference between the total valuation of the amount of transport demanded by users and the generalized price that this amount supposes for them. Thus, in the initial equilibrium (g^0, q^0), this surplus of users is given by the area **A**:

$$CS^0 = \frac{1}{2}(\overline{g} - g^0)q^0,$$

whereas in the new equilibrium (g^1, q^1) it would equal to the sum of the areas **A + B + E**:

$$CS^1 = \frac{1}{2}(\bar{g} - g^1)q^1 .$$

In the evaluation of a project, we do not seek the total surplus but the change that occurs in it as a result of the project, which greatly simplifies the work. In *Figure 4.1,* the **change in the users' surplus** is defined by the difference between the above two expressions and amounts to **B + E**. This surplus is explained by two factors: the effect of a price reduction on the initial users (area **B**) and the surplus of new users entering the market (area **E**). Formally, the change can be expressed as the sum of both areas:

$$\Delta CS = (g^0 - g^1)q^0 + \frac{1}{2}(g^0 - g^1)(q^1 - q^0) ,$$

which is equal to the so-called *rule of the half*:

$$\Delta CS = \frac{1}{2}(g^0 - g^1)(q^0 + q^1). \qquad \textbf{(4.11)}$$

Producers' surplus

The **producers' surplus** (PS) is defined as the difference between the total revenues and variable costs of all firms (public and private) that carry out the construction and operation of the transport infrastructure and services in a market. For simplicity, we assume that there is only one producer:

$$PS = pq - C. \qquad \textbf{(4.12)}$$

In the case of transport on own account, the agent acts as both the producer and user of its own transport services, which would force us not only to include as costs the costs associated with the operation and maintenance of vehicles but also to include the revenues in return for services rendered to agent. Therefore, there is no effect on the real surplus, so they are excluded from the calculation of CS.

The **change in producer surplus** as a result of a transportation project is given, from **(4.12)**, by the difference between the situation with and without the project, $PS^1 - PS^0$:

$$\Delta PS = (p^1q^1 - p^0q^0) - (C^1 - C^0), \qquad \textbf{(4.13)}$$

and its sign and value depends on how the project affects the incomes and costs of firms.[12]

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[12] As indicated above, the investment costs are included in the costs of the project (C^1). In calculating the social surplus, costs must be valued at the social opportunity cost.

Surpluses of taxpayers and rest of society

In general, the surplus of taxpayers is given by the difference between the revenues obtained through tax collection and the expenditure made by the payment of subsidies.[13] If we consider, for simplicity, that such taxes and subsidies can be expressed through a unit net tax per trip and denoted by ζ, the **change in the surplus of taxpayers** as a result of a transportation project would simply given by:

$$\Delta GS = \zeta^1 q^1 - \zeta^0 q^0, \qquad \textbf{(4.14)}$$

where ζq represents the tax revenue (net of subsidies).[14]

Measuring the **change in the surplus of the rest of society** as a result of a transportation project is much more difficult to define, since in many cases the resources are a common property and/or correspond to non-tradable goods. In the case of the dead and injuries on roads or in the case of environmental impacts, there are different methodological approaches to estimate their monetary values (i.e. the reduction of deaths and injuries or an increase in noise).

Given that most transport externalities are negative (other positive effects that could be called externalities are reflected in the indirect effects), we can reflect the benefit or harm of the project by defining the externality as a cost (E), not necessarily linear with the volume of production, as occurs for example with the barrier effect. Thus, the change in the surplus of the rest of society can be expressed as:

$$\Delta RSS = -(\mathrm{E}^1 q^1 - \mathrm{E}^0 q^0). \qquad \textbf{(4.15)}$$

In other cases, the determination of the change in the surplus of the rest of society requires a more detailed discussion of both the origins of such surpluses and the extent to which they are related to the transportation project. In accidents, for example, insurance premiums paid by transport users and producers reduce their surpluses by increasing the surpluses of insurance companies, which must also be considered in calculating the social surplus. In the rest of society group, we will only include the effects of accidents that have not been internalized.

Indirect effects in the remaining markets ($i \neq j$) can be represented as changes in their corresponding equilibria ($q_i^1 - q_i^0$, with and without project, respectively) using D_i to denote the degree of distortion in these markets, measured as the difference between the price and marginal cost in each of them. Thus, the set of indirect effects would be given by:

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[13] Also for revenues from privatization or revenues collected by the use of infrastructure (these appear in producer surplus of public enterprises if they have been defined). As always, the important thing is to avoid double-counting.

[14] We assume that they are collection taxes and are not intended to internalize an externality. If the tax is intended to internalize an externality, the income of taxpayers will appear with a minus sign in the balance of producers or users, and the rest of society, so the net effect on social surplus is the negative value of the externality.

$$\sum_{i \neq j} D_i (q_i^1 - q_i^0) \, ,$$

with the overall sign positive, negative or zero.

Determination of change in social welfare

As in the resources approach, once defined and calculated the surpluses of the various actors involved in any transport market, and having added the significant indirect effects, it is possible to determine the **change in social welfare** associated with a proposed project that modifies the surpluses of the different actors in the equilibrium *without* project in that market.

Under the assumption that a monetary unit has the same social value irrespective of what social agent receives or loses it, and that factor prices reflect their social opportunity costs, the idea is to add the changes taking place in surpluses for each of the agents concerned:

$$\Delta SW = \Delta CS + \Delta PS + \Delta GS + \Delta RSS. \qquad \textbf{(4.16)}$$

That is, according to the above expressions and adding in the indirect effects, the change in social welfare is now equal to:

$$\frac{1}{2}(g^0 - g^1)(q^0 + q^1) + (p^1 q^1 - p^0 q^0) - (C^1 - C^0) + (\zeta^1 q^1 - \zeta^0 q^0) - (\mathrm{E}^1 - \mathrm{E}^0) + \sum_{i \neq j} D_i (q_i^1 - q_i^0),$$

where, again, for the evaluation of a project this amount must be calculated in each of the periods (ΔBS_t) in which the project generates effects and compared with the corresponding equilibria *with* and *without* project.

The expression equivalent to (**4.9**) to measure the **total change in social welfare under the surpluses approach** for a project whose effects take place between $t = 0$ y $t = T$ is:

$$\begin{aligned} \Delta SW = \sum_{t=1}^{T} \delta^t \Bigg[& \frac{1}{2}\left(g_t^0 - g_t^1\right)\left(q_t^0 + q_t^1\right) + \left(p_t^1 q_t^1 - p_t^0 q_t^0\right) - \left(C_t^1 - C_t^0\right) + \\ & + \left(\zeta_t^1 q_t^1 - \zeta_t^0 q_t^0\right) - (\mathrm{E}^1 - \mathrm{E}^0) + \sum_{i \neq j} D_{it} (q_{it}^1 - q_{it}^0) \Bigg], \end{aligned} \qquad \textbf{(4.17)}$$

where δ^t represents the discount factor.

Note finally that this expression makes a mere aggregation of the surpluses of each agent without placing any weight between them, which implicitly corresponds to attributing the same weight within the sphere of social welfare. In addition, indirect effects are aggregated without knowing their distributions among the different individuals involved. We now examine in more detail the issue of equity associated with public projects and policies.

4.3. Efficiency and equity in project evaluation

Most public investment projects cause redistribution impacts affecting the different agents in society. There are many projects whose costs are borne by all taxpayers, even though the benefits are concentrated in a particular group of society. Other projects benefit larger groups but concentrate their negative effects on a particular social group. Sometimes, the effects go beyond the limits of the target group, with repercussions on the welfare of the wider population. Other times, the final beneficiary of the policy is difficult to determine *ex ante*.

Distributive equity refers to a project's impact on the net available income and the value in terms of agents' wealth. Furthermore, in the case of investment projects in transport infrastructure, the occurrence of heterogeneous spatial effects is common, which favors in varying degrees different territorial areas. We will refer to the latter case as impacts on the location of economic activity.

The use and enjoyment of non-renewable resources by the current generation will positively or negatively affect the potential for future generations. This effect is stronger depending on the life of the investment, the use of non-renewable resources and the existence of harmful and irreversible impacts on the environment. One way to consider this impact on *intergenerational equity* is through discount rates.

In each society, it is possible that different socioeconomic groups have strong preferences for different modes of transport. A simple study of transport demand would identify different groups of users and the potential benefits that such investments could bring them. In this sense, an investment in a particular mode of transport leads to changes in the welfare of economic agents. The decision to invest in transport infrastructure is usually a compromise between efficiency and equity. In cases where the application of the efficiency criteria and equity considerations come into conflict, the decision depends on the preferences of the public decision-maker. Given the extremely subjective nature of the redistributive aspects, tools designed to assist in the decision-making process cannot provide unique solutions. Instead, they seek to provide mechanisms to guide the decision-maker without judging to what extent some projects are better than others.[15]

In CBA, weighting is rarely used for reasons of equity and, thus, equal weight is implicitly given to all individuals. However, economists tend to consider that the social value of an additional Euro obtained by an individual with a high income has a lower impact on social welfare than when the Euro is received by an individual with a low income. According to this criterion, individuals with lower incomes should have a greater weight in the CBA model than that applied to individuals with higher incomes.

However, this practice has been questioned from a theoretical and an empirical point of view, for example, by the World Bank, which no longer uses any weights in its CBAs. The main theoretical

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[15] A more detailed description of these resources can be found in Appendix III and in the working paper "Los impactos sobre la equidad distributiva y espacial de los proyectos de infraestructura de transporte."

criticism is based on the risk of accepting inefficient project implementation, not because of the value resulting from the project itself, but because of satisfying the criterion of inequality among different income groups. The latter case would be undesirable because the project would achieve a redistribution of income that might, through the use of other fiscal mechanisms, be achieved at a lower cost. In practice, the use of distributional weights is subjective and evaluators do not usually feel comfortable deciding between functions of weights. Another drawback is the enormous effort in time to identify the benefits for each of the groups. These two reasons together with the argument of inefficiency cast doubt over the use of distributional weights.

It is usual that much of the benefit of a project is capitalized on the value of the land or real estate assets. In the same way that noise negatively affects the values of homes near an airport, the values of homes and businesses goes up when a project increases accessibility to the area where they are located. From this fact it follows that it is often irrelevant to assign benefits to affected groups immediately if, later, the owners of fixed factors just capture the benefits generated by the project. At the same time, this allows the identification of agents that can contribute financially to the construction of the project, resolving to some extent the problem of equity, in addition to making viable projects in situations of budget constraints.

On the other hand, in relation to spatial equity, the choice of the location and route of transport infrastructure determines which geographical areas benefit from the investment and which do not. Again, the criteria of efficiency and equity might not be compatible, but in this case the impact on social welfare is not as intuitive as in the case of distributional equity. In this sense, the national investment strategy to increase efficiency and equity is not obvious.

One method that helps understand this dilemma is to use models of economic geography. The implications of investment in transport infrastructure, translated into a reduction in transport costs, depend on mobility in the labor market, regulating wages, market structure, the degree of the specialization of production and the development gap between regions, as well as the type of infrastructure that we want to implement. The result of this policy can affect the location of firms and workers and thereby the growth rates in certain geographic areas.

Although a new or better transport connection between a developed region and a less developed one can be beneficial for both, it is also possible that the latter region needs to undergo a process of adaptation to a more competitive environment. High transport costs are a natural barrier to trade that can benefit local industry. The ability and necessity of this region to adapt to the new environment and find new alternatives that more efficiently redirect its manufacturing sector will be key factors to whether the investment in the transport infrastructure will be beneficial for this region (see Appendix III).

5. IDENTIFICATION OF SOCIAL COSTS AND BENEFITS

The economic evaluation of any transportation project, defined – as discussed above – in terms of an intervention in one or more transport markets, entails the need to identify clearly the types of effects that this project generates for society as a whole regardless of the method chosen for calculating the changes in social welfare.

Throughout this chapter we will discuss in detail investment costs, producers' costs, users' costs and changes in external effects as well as their related subcategories.

5.1. Investment costs

Traditionally, **investment costs** for a transportation project are associated with the process of building a new infrastructure (e.g. the construction of a new port terminal), the reform or amendment of an existing infrastructure (e.g. the expansion of an airport) or the acquisition of assets required for the implementation of new services or the modification of existing ones (e.g. the purchase of vehicles to increase or renew a bus fleet to offer new routes or improve the quality of existing ones).

With a chronological approach, **four main subcategories of investment costs**[16] may be considered, although not all of them are present in all projects:

- **Planning costs**: Those associated with technical and economic studies prior to project commencement. Such costs are higher the greater the project complexity, the number of alternatives to consider and the number of agents affected, and the more complex the institutional context in which the transportation project develops.
- **Acquisition and land preparation costs**: Transport infrastructure often require large extensions of land, either concentrated in one area (to build an airport) or spread over many kilometers (roads or railways). Sometimes it is also necessary to reserve sea and/or air space so that other activities do not interfere with the normal operation of the facility. In all cases, acquisition costs are related to the process of land purchase, which in turn maycan involve expropriation procedures. The cost of demolishing pre-existing structures and earthworks prior to the commencement of works could be included within this subcategory or even within the next one.
- **Construction costs**: Those costs related to building infrastructure and/or the acquisition of assets to be used during the project life. They also include materials consumption, including costs of labor, energy, professional fees and other contingencies if they are not accounted for under another category. Such costs would be the opportunity costs from

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[16] These categories are those proposed by the **European Commission (2006)**.

the point of view of society; for example, in the case of labor, as shown below, there are already estimates of the shadowwage for most European regions.[17]

- **Interruption costs**: These are associated with alterations that the construction of a specific transport infrastructure generates to users and society as a whole and which take the form of noise, nuisance, congestion, temporary changes in other modes, etc. Some of these costs are included within external effects, although this is not always the case since they can be transitory elements that finish at the end of the investment period.

Empirical evidence has shown that most projects incur in additional costs over the initial budget.[18] Sometimes, these deviations are accepted and tolerated by norms, establishing some margins of reference. In *ex ante* project evaluation, it is preferable to provide the deviation with a random nature and model it according to a probability distribution. In *Appendix IV* it is argued that some mechanisms of funding and/or types of contract favor this overinvestment. Therefore, if the evaluation is carried out *ex ante*, it should take into account this information when estimating possible cost overruns.

By contrast, as addressed practically in the next chapter, in projects evaluation it is necessary to value investment inputs[19] at its social opportunity cost. In general, the use of market prices for each of the project assets can be a good approximation. However, when there are significant distortions in factor markets it is necessary to use shadow prices that realistically reflect the opportunity cost of such inputs.

The economic justification for using market prices under competitive environments as a measure of the opportunity cost is that, in equilibrium, marginal cost and price match. Moreover, they correspond to the value of the marginal productivity of the last unit in the case of inputs and value to society in the case of production. However, the mere existence of taxes or subsidies involves the violation of such a principle.

The economic valuation of labor constitutes a clear example of the use of shadow prices. Depending on the nature of such work and where it has previously been employed, the gross wage can be a good approximation or it might be necessary to use some correction. For example, if there is voluntary unemployment, the cost of hiring an unemployed person will be given by wage net of taxes.

Another example is given by the use of land. In this case, the accounting and registry value does not necessarily represent the factor opportunity cost. This is characterized by the profit lost in the

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[17] See **del Bo *et al.* (2009)**.

[18] For a more detailed analysis, see **Flyvbjerg *et al.* (2003)**.

[19] Sometimes these inputs are not production factors in the strict sense but outputs of other industries. This fact does not change the valuation criterion: to calculate the social opportunity cost of the output used in the project.

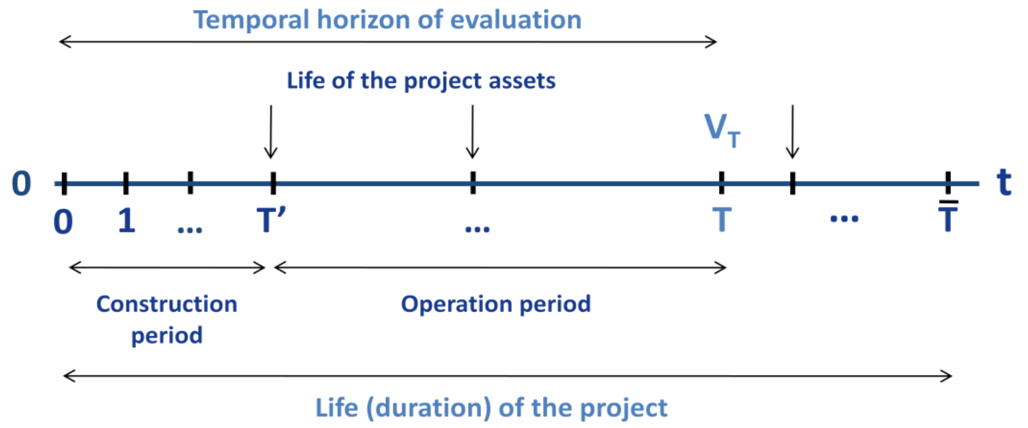
best possible use of such land. For instance, if it was employed in agriculture, the opportunity cost is the value of the agricultural production during the time horizon over which that factor is used. One additional problem with land use is the existence of speculation and externalities in nearby fields. That is, the construction of infrastructure can generate capitalizations that are anticipated by economic agents. Moreover, it might be possible to use land that is not subject to the free market such as natural parks, so the valuation is more complex than in the case of other factors that are not fixed.

The terminal value of an investment project

The **investment costs** of a project are expressed in the monetary value of the resources that society provides for that project to be carried out and generate benefits and costs for society during a certain period of time, which constitutes the **duration or life of the project**. When the life of the project coincides exactly with the **temporal horizon of evaluation** (i.e. the period considered by the evaluator during which benefits and social costs are computed to calculate the NPV), the project ceases to exist at the end of both and it is not necessary to make any additional calculation. However, this is usually not the case. In most transport projects, the life of the project extends beyond the horizon of the evaluation, leading to the concept of the **terminal value of a project**.

> The terminal value of a project (V_T) is what it brings to society beyond the horizon of the evaluation.

Figure 5.1: **The terminal value of a transportation project**



In *Figure 5.1*, the effects of the project considered occur during $\overline{T}$ periods (years), during which the effects of the initial investment arise. This value depends mainly on the type of project, the technology used and its development (technical progress of society and level of obsolescence of the assets involved).

By contrast, the **horizon of the evaluation** (from **0** to **T**) is usually exogenous to the evaluator and is generally linked indirectly with the life of the project assets and with the fact that extending the evaluation over a longer period may result in severe information problems on the studied variables. In most infrastructure works, an evaluation of 30 years is reasonable, although this period should be extended or reduced depending on the life of most of the assets involved.

> In calculating the NPV, the terminal value of a project (V_T) (discounted appropriately) should be included in the flow of the project's benefits and costs.

The determination of the terminal value (V_T) of a project involves calculating a value too distant in time and influenced by many variables, thereby generating a significant dose of uncertainty. There are two main approaches:

- **Obtaining the terminal value from the initial investment**. In this case, the value of V_T is obtained as a function (usually a percentage) of the initial investment. Despite the apparent simplicity of this technique and its possible justification based on the idea of the depreciation of assets used in the project, the disadvantages are also significant: what it is obtained in this way is a **residual value** of the investment, which is not necessarily linked to the social benefits and costs of the project, but instead to the (average) life of the project assets.

- **Obtaining the terminal value from the discounted value of benefits and costs incurred after the end of the evaluation horizon**. In this case, we explicitly consider that the life of the project extends beyond the horizon of the evaluation, and this is incorporated endogenously by matching V_T with the present value at T of the flow of the social benefits and costs that the project provides between T and $\overline{T}$. Despite its consistency, the main difficulty of this method is that it requires a greater volume of calculations. It is actually equivalent to extending the horizon of the evaluation to match the project life, or with a date close enough to it.

5.2. Changes in producers' costs

The second category to consider when identifying the benefits and costs of a transportation project refers to the changes that the project generates on producers' costs, where producers are those agents operating infrastructure or transport services.[20] For this reason we consider specifically as producers' costs those costs related to maintaining and operating the infrastructure, vehicles and other assets used in transport markets. When information is available on the effects on the firms

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[20] Investment costs can also be included within this definition because they are also producers' costs. However, because of their special significance and particular characteristics, we address them separately, as discussed in the previous section.

participating in the market, this is one of the most simple to compute and less controversial elements, whereas if the information is limited or incomplete we might have to resort to modeling using probability distributions in the way already explained in earlier sections of this **GUIDE**.

Maintenance costs are needed for infrastructure, vehicles and other assets to remain in a proper operating condition throughout the life of the project. Their magnitude varies with the type of asset and its technical characteristics. Decisions on maintenance costs are reflected in the life of the assets and, in general, in their operating conditions.

Operating costs are related to the normal functioning of the infrastructure, vehicles and other assets within the transport markets. Although some components can be fixed, some of the costs of operation are proportional to the demand and, contrary to what happens with investment costs, they are incurred throughout the project life (as happens with maintenance costs as well). From the point of view of its origin and possible allocation for both the operating and maintenance costs, it may be useful to distinguish three subcategories:

- **Costs related to vehicles or assets in general**. This section mainly includes the costs of maintenance and repair of such assets as well as costs related to staff that operate them and essential supplies for their functioning. The annual depreciation of the assets, reflected in the amortization values, should not be included as a cost because the total asset value is already computed through the investment.
- **Costs related to utilization time.** These are costs that depend on the number of hours that vehicles are in service. In this case, they are mainly characterized by the use of personnel required for passenger and cargo services.
- **Costs related to distance traveled**. These are where the main element is usually the cost of fuel.

It is important to note that these subcategories will vary depending on the specific mode, and even within the same mode, they will vary depending on the technology and type of traffic considered.

5.3. Changes in users' costs

Analogous to the calculation changes introduced by a transportation project on producers' costs, a similar procedure should be carried out on users' costs. Based on the definition of generalized price made in the previous chapter, the main changes relate to two main elements: the time savings accruing to existing and diverted users and the willingness to pay of new users.

Time savings and willingness to pay

The evaluation of a transportation project consists of comparing the situation that occurs in the market with project and what would have happened without the project. For that purpose we compare the demand in both situations. Moreover, we should distinguish between existing traffic and traffic induced by the project, which could be diverted traffic and generated traffic:

- The existing demand or traffic is given by those users who were already in the transportation market before the project and who would have stayed even if the project had not been carried out.

- Diverted traffic is the traffic that, as a result of the improvement made by the project, leaves other modes or infrastructures of transport to benefit from the reduction in the generalized price in the primary market.

- Generated traffic would be the one that would not exist without the project. It can be referred to the same users that increase the number of trips or to new users whose marginal benefit of making the trips was lower than the generalized price without the project.

The source of the diverted traffic can be another route, another time or another mode of transport, but for evaluation purposes the primary issue is to specify the savings that occur. The time savings are multiplied directly by the number of users on existing traffic, whereas for the diverted and generated traffic the benefit is calculated as half the time savings to incorporate the various willingnesses to pay of users in these categories.

The problem of capacity

The measurement of time savings is related to capacity problems. Transport infrastructure has highly differentiated characteristics between different modes of transport in terms of technological aspects. Thus, for example, a road and an airport have little to do with each other regarding the interaction with (and between) vehicles used in each infrastructure. Although in the case of the road there are thousands of individual decisions when entering to use the infrastructure and each user has a different type of vehicle and travels at different speeds, in the case of an airport the number of aircraft using the infrastructure for a given day is planned beforehand is more homogeneous in terms of technical characteristics. Moreover, the use of the airport is highly coordinated for reasons of operational security. Even if we descend into each mode of transport, there are also important differences between types of infrastructures.

Each type of infrastructure (but not every mode of transport) has its own technological characteristics that are marked by its function within a system of transport, the types of vehicles and the operation thereof. However, despite the technological differences between types of transport infrastructures, they all share one common characteristic that defines them and that from a conceptual point of view constitutes the definition of capacity: the maximum flow of vehicles per unit of time (cars, planes, trains or ships) or final users (passengers or freight) with particular levels of quality and safety.

Choosing which of these two possibilities, vehicles or users, is more relevant in the evaluation of projects depends on the type of infrastructure under evaluation. As we shall see, in every mode and type of infrastructure, the factors determining the capacity are different and, therefore, in each case we choose the measure of capacity that is more useful for the determination of the relationship between demand and capacity.

Likewise, the measures of infrastructure capacity require a time reference to be included in the definition; for example, the flows are per unit of time. This unit of reference varies depending on the case. Generally, the use of flow per hour will be more common, while in other cases it could be sufficient to use larger time references such as years to calculate the time. In any case, in measuring the maximum capacity of an infrastructure it is important to distinguish between two concepts:

- **Maximum theoretical capacity**: it is determined by the design of the infrastructure (physical characteristics, dimensions, additional equipment, etc.) and attends to certain levels of quality and safety.
- **Operational capacity**: it usually exceeds the theoretical capacity, since it is always possible to accommodate higher flows than the maximum reference flows, although it inevitably worsens the conditions of quality for users.

These two concepts of capacity depend on a number of physical and operational characteristics that differ between different modes of transport. We should also consider that the capacity of a transport infrastructure varies depending on the composition of the traffic that uses it. Thus, for example, the percentage of heavy vehicles on a highway, the mix of aircraft at an airport or the combination of train types and ships in ports are all important factors when measuring capacity. Similarly, if we descend to the level of final users, the composition of types of passengers and freights can also affect maximum flows that can be supported by the transport infrastructure.

Table 5.1: Determinants of infrastructure capacity by mode of transport

	Main characteristics	**Unit of measurement**	**Additional considerations**
Roads	Number of lanes and width of the road. High capacity roads	Vehicles/hour	Percentage of heavy vehicle traffic
Airports	Number of runways and length. Large numbers of additional services	Number of operations /hour	Existence of support systems in flight
Ports	Existence of a container terminal, type of additional services	TEUs/docks linear meters/year (for containerized goods) and tons/day (for bulk and other goods)	Characteristics of ships calling
Trains	Electrification of the line, existence of double tracks	Movements/day	Signaling systems and number of tracks, stations.

Source: Authors

Improvements in the quality of existing services

Improvements in the quality of existing services (particularly those related to the convenience and reliability of services) can be another potential benefit in the evaluation of transportation projects. These changes in quality are valued by consumers willing to pay for improvements in their level of comfort or the services offered by a particular product.

Changes in quality are reflected by the generalized price that incorporates not only the monetary price paid for the service, but also all the changes associated with the convenience and comfort of travel. The main difficulty in assessing changes in quality is that, unlike the price paid for the service, the quality is not a good that is directly exchangeable in a market and therefore, there is no single, objective quantitative assessment of it. Its assessment will depend to a large extent on previous quality levels, consumer preferences, the existence of alternatives and the context in which it occurs.

Changes in quality are usually evaluated by using a methodology applied to non-tradable goods. These tools provide insight into the willingness to pay of individuals for changes in quality and comfort levels and, therefore, they can approximate the changes in consumer surplus or resources that must be incorporated into the calculation of the NPV.

5.4. Changes in external effects

When the production or consumption of goods affects third parties, we are in the presence of an externality (e.g. pollution or noise suffered by residents of an area through which a mean of transport that they do not use goes). Whether the externality is internalized (Pigouvian taxation) or not the social cost must be accounted for.

Although externalities can be positive or negative, we refer here to the negative ones. The positive ones will be covered in the additional economic effects, such as agglomeration economies. In the case of the **Mohring effect** and for the purposes of evaluation, they are included in the direct effects for the existing and diverted traffic, and within the indirect effects for those passengers who remain in other modes of transport in secondary markets in which there are positive externalities characterized as the **Mohring effect**.

Negative externalities

The list of negative externalities arising from transport projects is long because of the numerous impacts that this industry generates. The most obvious problems are air pollution (both at the local/regional level and on a global scale, such as the so-called "greenhouse effect") that is produced by all types of vehicles burning fuels and the noise generated by the engines of such vehicles. The infrastructure necessary for the development of transport activities also has an impact on the environment and the welfare of agents who are not users of this infrastructure. Generally speaking, the main negative externalities associated with transportation projects can be summarized in Table 5.2.

Table 5.2: **Major negative externalities of transport modes**

	Train	**Road**	**Air**	**Sea**
Atmosphere	Pollution in electricity generation	Local and global pollutant emissions	Pollution areas in airports and global air pollution	Global pollution burning fossil waste
Land use	Barrier effects to wildlife	Barrier effects and moving land for construction	Airport barrier effects to wildlife	Modification costs of river channels
Solid waste	Close lines, obsolete equipment	Scrapping old vehicles. Oils used. Road construction materials	Obsolete aircraft	Obsolete ships
Water	Diversion of natural resources for infrastructure construction	Surface and groundwater pollution by waste	Diversion of natural resources for infrastructure construction. Draining tracks	Diversion of natural resources for the construction of canals. Barrier effect on coasts and beaches
Noise	Problems in stations and on inland environments	Problems in large cities and road environments	Problems in environments of airports and aircraft approach areas	–
Accidents	Derailments and collisions. Ability to discharge polluting substances	High number of fatalities and injuries. Discharge of pollutants	High accident severity in terms of fatalities	Discharge of pollutants and accidents involved
Other impacts	–	Congestion on certain roads or road sections	Congestion at airports. Delays for travelers and costs for companies	–

Source: OECD (1988).

With the exception of accidents and congestion, most of these externalities are environmental, in the sense that fulfill three important conditions from the point of view of their identification: their origins are in a production or consumption activity directly linked to transport, the associated economic activity involves an environmental impact and this causes a change in the welfare of others not directly related to its origin.

Externalities (i.e. the value of the change in welfare of the rest of society) are not necessarily constant over time, which entails an additional difficulty when quantifying their effects on . It might well be that externality increases in some years and decreases in others.

Moreover, very often the environmental impacts are non-rival. That is, they affect several people at the same time without varying the individual value of the effect. The movement of a train can cause vibrations in the ground that can be felt throughout a whole population center. If the fact of having more or less residents does not change the discomfort that they perceive with the vibrations, then it is said that the good (or bad, in this case) is not rival. The most significant implication of non-rival goods for cost-benefit analysis is that the external cost of each resident is added to produce the overall gain or loss of welfare. When valuing environmental externalities an average value per person it is usually obtained, and this is then multiplied by the number of people affected. If the externality is positive for a part of the population and negative for another, the aggregation of the individual values indicates if the externality is positive or negative for the rest of society. This balance must be incorporated into the corresponding cost-benefit analysis.

One way to first identify and then value (see *Chapter 6*) externalities for their incorporation into the cost-benefit analysis is done through **dose–response functions**. In terms of the above analysis, the transport activity would be the dose, whereas the response would be the impact or environmental change. Finally, it would be about trying to measure the externality associated with this change. For example, an increase of *k* km/year of total motor vehicle traffic (the dose) results in an additional impact of *z* parts per million concentration of particles of a certain size into the atmosphere, which influences the deterioration of health or visibility or the preservation of materials (the response), which in turn results in *m* Euros equivalent to the loss of welfare of the rest of society (the externality).

Therefore, and according to this reasoning, the main externalities associated with transportation projects can be identified by the type of environmental impact they produce. At the same time, externalities vary with the type of transportation or infrastructure, depending on the stage of the project (construction or operation) and on how it translates the ultimate effect to people, which can be of different nature. Thus, we might have:

- **Noise**. This is more likely to affect consumer activities than production activities. It also affects health. Mainly relevant to road and air transport in the operations phase of infrastructure and railways near densely populated areas.
- **Landscape**. In principle, it affects practically all infrastructures. It usually involves a loss of recreational or aesthetic value.

- **Air pollution**. Some means of transport, such as those using electricity (railways, trams, etc.) do not usually generate environmental pollution in situ, but instead from the site of energy production. Pollution affects consumer activities as well as production, human health, the conservation of materials, visibility and climate change, which in turn has a variety of effects.

- **Soil contamination**. Produced mainly by road transport, its effects can be seen in the same place or in other nearby areas. Its effects on production, consumption and human health can be deferred over time.

- **Water pollution**. More directly generated by waterborne transport or by waste from other modes, it can affect both consumer and production activities. The impacts on species can in turn be perceived negatively by people.

- **Climate change**. Greenhouse gases from transport have more long-term effects of different natures and complex quantifications.

- **Vibrations**. Mainly from rail and air transport, they can interfere with certain production and consumption activities.

Congestion as an externality

In relation to **congestion**, it emerges by a mismatch between demand (number of users who want to use an infrastructure or service at a given time) and supply (capacity to accommodate those users at the same time). This is a particular feature of transport markets, because in almost every case demand is rarely constant over time. Thus, infrastructure and services are designed with a specific capacity that can be modified in the long-term but is fixed in the short run.

Congestion can be viewed as an externality in the sense that it is an effect generated by some agents that do not take into account the costs they are imposing on the rest of the infrastructure users. But this externality can be defined as "internal" to the transportation market (since all the users affected by a problem of congestion cause and suffer the costs associated with the saturation of the infrastructure).

Because of this internal feature for the transport industry, the costs of congestion are often excluded from the quantification of the negative externalities generated by transport. Although this methodology can be appropriate when developing social accounts of the transport industry as a whole, the magnitude of these costs means that this effect could hardly be ignored and that the analysis of congestion is highly relevant. Similarly, the search for solutions to reduce congestion costs is often a major concern of the authorities responsible for transportation. From a practical standpoint, however, it does not create any difficulty for the economic evaluation of projects since the level of congestion (or its change, both positive and negative) is reflected in the variation of travel times, as was discussed above.

The cost of accidents

Given its nature, all transport activities imply a risk of suffering an accident (numerous vehicles moving at high speeds and using a common infrastructure). Either by mechanical failure or, more commonly, by the influence of human errors, accidents involving vehicles are an event that occurs in all modes of transport. However, there is no consensus to assess which mode of transport has a lower probability of an accident. This is because, for technological reasons, the various modes of transport are not easily comparable, which makes it complex to find an exposure variable common to all of them that adequately reflects their characteristics.

In any case, from the point of view of identification and of changes in accident costs related to the evaluation of transport projects, it is clear that the analysis of how individuals make their transportation decisions in a scenario where the probabilities of having an accident are known generates a similar problem to that described above for environmental externalities. Transport users who use their own vehicles to travel take into account some of the costs associated with the possibility of having an accident, but not all, because if it happens, some of those costs are transferred to society as a whole and to other individuals. Consequently, the use of private vehicles can be excessive from a social point of view because it is based on price signals that do not reflect to the user all the costs.

To study the costs associated with accidents, three main categories are usually considered:

1. **Costs derived from loss of life,** generically called **the value of a statistical life**.
2. **Welfare loss for family and friends**, including relocation and funeral expenses, which must be assumed by the family of the victim, and also those associated with pain and suffering.
3. **Other costs,** including hospitalization costs, administrative costs, legal costs and damage to physical assets.

The first of these categories, whose quantification is addressed in the next chapter, has generated most interest from the standpoint of cost-benefit analysis. The second category has been estimated by different methods based on stated preferences about willingness to pay to avoid the risk of the accident of a relative, and the values obtained are about 40–50% of the first category. Finally, the third category of costs, which are those borne by society as a whole, has an order of magnitude much lower than the previous two, between 5–7% of the value of costs resulting from the loss of life and the direct costs, although they are still not negligible amounts.

6. QUANTIFICATION AND VALUATION OF SOCIAL COSTS AND BENEFITS

6.1. Valuation methods and criteria

Having identified the different components of benefits and costs associated with a particular public intervention, the last step towards the completion of the economic evaluation of a transport project is to numerically quantify these impacts and assign them a monetary value. For example, if this is a project that saves time for the users of transport modes, we will calculate the time saved and then this will be valued by applying the appropriate value of time savings; these time savings can, in turn, involve operational cost savings that must also be quantified and valued.

The above example raises two contrasting situations regarding valuation: the valuation of time savings by applying a value obtained indirectly from empirical studies and the costs of materials and spare parts, or fuel, for which we have a starting point in their market prices. In summary, in the valuation section we must consider goods for which there is a market, and whose values, therefore, are relatively simple to obtain (corrected for shadow prices), and goods for which there is no market so that we should estimate their values for the project or transfer them from other existing studies.

In general, any process of the quantification and economic valuation of the benefits and costs associated with transportation projects is always complex because of the coexistence of various factors that cannot be excluded from the analysis:

1. First, as discussed in previous chapters, there might be uncertainty about the consumption of physical factors. This uncertainty relates to both the project situation (i.e. the future development of the transport market after the intervention) and the base case (i.e. the situation without project, which reflects what would have happened in the market if no intervention had taken place). In either case, the main problem is estimating the consumption of inputs that will occur in the transportation market over the lifespan of the project. In many cases, this cost uncertainty is closely related to the uncertainty of demand, because a part of the costs – variable costs – depends on the number of users and intensity of use of infrastructure and transport services.

   There is no a single option to address this problem within the framework of the socioeconomic evaluation of transportation projects. As far as possible, and provided that it is about processes under relatively simple physical laws, we should draw on mathematical formulas or expressions derived in the field of transport engineering. These are issues such as linking fuel consumption and vehicle speed or power consumption in terminals and passenger volume. Technical calculations associated with the infrastructure construction and implementation of certain transport operations sometimes allow the use of this approach, although it generally requires a high degree of collaboration between engineers and economists with the aim of identifying the true opportunity cost.

Other times it is possible to use firm's accounts to obtain information on consumption and the costs of certain factors. However, accounting criteria do not always respond to the principle of opportunity cost and can be distorted by legal or fiscal constraints. Moreover, in many cases the level of aggregation is not appropriate because the information is presented at the firm level, rather than at the level of aggregation required by the project (for example, for a particular route or part of the infrastructure).

When costs under review do not allow the use of formal expressions or the accounting information cannot be directly applied, it can be feasible to use statistical simulations or econometric estimates based on data or values from other projects. The main risk here is the validity of the results, which is determined by the concurrence of circumstances and common patterns in the elements being compared.

2. By contrast, even in cases where the uncertainty associated with the physical consumption of productive factors can be reasonably addressed by the procedures described, there is a second major problem in measuring the costs of a transportation project. The determination of the proper monetary valuation of such consumptions, i.e. the unitary value or price that accurately reflects the opportunity cost of resources from the point of view of society as a whole.

   In the absence of significant distortions on the functioning of the economy, market prices are a good approximation of the social opportunity cost of goods and services purchased by consumers or users. When supply adequately reflects the plans of producers and demand consumers' desires, prices tend to equal marginal costs which, in essence, represent the cost to society – in terms of resources consumed – of the production of the last unit of product or service. On the contrary, if markets do not efficiently allocate the resources, it would be necessary to adjust the prices by using shadow prices.

6.2. Valuation and quantification of investment costs

There is ample documented experience showing that most interventions in transport, particularly in infrastructure construction projects, have an optimistic bias towards the underestimation of costs. These deviations also hold for long periods (i.e. systematic bias). This result reinforces the idea – already presented in *Chapter 3* of this **GUIDE** – of the need to incorporate uncertainty into the evaluation process from the beginning, using probability distributions to model possible upward deviations in the investment costs in relation to the costs originally budgeted.

The procedure known as *Reference Class Forecasting* mainly consists of three stages: first, the identification of a sufficient number of past projects with similar characteristics to the project under evaluation.[21] This selection must be statistically significant. Second, considering the

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[21] See **Flyvbjerg (2008)**.

obtained database the costs' probability distributions are estimated for the reference class that is determined by the type of project. Finally, the project is compared with the distribution obtained.

The most complicated part of this procedure relates to the compilation of databases necessary to establish references. By applying this approach it could be proposed to increase capital costs by a certain percentage, as shown in *Table 6.1*. These percentages provide reference values for modeling the behavior of the random variable "investment deviation."

Table 6.1: **Applicable capital costs uplift (average cost escalation)**

Categories	Types of projects	Increase
Roads	Motorway Trunk roads Local roads Bicycle facilities Pedestrian facilities Park and ride Bus lane schemes Guided buses on wheels	22%*
Rail	Underground Light rail Guided buses on tracks Conventional rail High-speed rail	34%*
Fixed links	Bridges Tunnels	43%*
Building projects	Stations Terminal buildings	25%**
IT projects	IT systems development	100%**

* Based on data for the average increase of costs in Europe in accordance with Flyvbjerg *et al*. (2004).

** Pragmatic estimation based on a rank in agreement with MacDonald (2002).

Source: Bickel *et al.* (2006) with data from different sources.

6.3. Time savings and willingness to pay

To determine how to value travel time savings, the evaluator of a project has the following options:[22]

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[22] This is the approach proposed in IDB (2006).

1. Conduct **a specific study** for the users of the particular case evaluated based on a methodology theoretically sound and empirically contrasted at an international level. This is the best option subject to the availability of financial resources and time.
2. When the previous option is not feasible, there are **recommended values that can be applied** at a national or international level for the social evaluation of transport projects.

3. Finally, if these recommendations are not available, **data from other surveys** or similar countries might be transferred, making then the proper adjustments. The problem associated with value transfers between countries can be softened in different ways, although one of the most used options consists of adjusting values according to real *per capita* income levels expressed as Purchasing Power Parity (PPP).[23]

There are several additional considerations that can be useful in the practice of evaluation. First, it is often assumed that values grow at the same rate as real *per capita* income, i.e. a unitary income elasticity is assumed. Other studies recommend performing a sensitivity analysis with income elasticities ranging between 0.7 and 1.[24]

By contrast, it is also possible to consider **different travel times depending on travel conditions**. Thus, it is often recommended to use waiting time values and time walking values above the value of time inside the vehicle, increased by a factor of between 2.5 and 2, respectively. For delays (congestion), the recommendation is to multiply travel time in the vehicle by a factor of 1.5. Some studies have considered how the values of time change by taking into account other factors such as comfort, convenience, reliability or safety. Although it is recognized that values tend to be higher in uncomfortable, unsafe, stressful or uncertain conditions, there are no general recommendations in this regard.

Finally, with regard to **small times savings**, the most common practice in their valuation is to assume that the value of time increases linearly with the size of savings, so they tend to apply the same values used to value savings of greater magnitude.

Tables 6.2, 6.3 and *6.4* offer, as a reference, values set for Spain in the European project HEATCO. In the absence of specific studies or national recommendations, this is the most extensive and recent reference. The same study compiled the values to be applied in other EU countries, but it is worth noting the absence of values for the maritime mode because of the scarcity of empirical evidence.

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[23] Along the same lines it is possible to estimate probability distributions for the time saving values taking into account data from previous studies (see working paper "Bayesian posterior prediction and meta-analysis") and obtaining probability distributions for the values (via the Bayesian forecasting).

[24] See working paper "Producer and user costs estimation in transport projects evaluation."

Table 6.2: **Travel time savings values in work time for Spain (passengers)**[*]

	Air		Bus		Car/Train	
	Spain	EU25	Spain	EU25	Spain	EU25
€$_{2.002}$	30.77	32.80	17.93	19.11	22.34	23.82
€$_{2.002}$ PPP adjusted	35.74	32.80	20.83	19.11	25.95	23.82

[*] At factor cost: passengers per hour.

Source: Bickel *et al.* (2006).

Table 6.3: **Travel time savings values for non-work time for Spain (passengers)***

	***Commuter* Short distance**						***Commuter* Long distance**					
	Air		**Bus**		**Car/train**		**Air**		**Bus**		**Car/Train**	
	Spain	**EU25**	**Spain**	**EU25**	**Spain**	**EU25**	**Spain**	**EU25**	**Spain**	**EU25**	**Spain**	**EU25**
€$_{2.002}$	12.72	12.65	6.12	6.10	8.52	8.48	16.33	16.25	7.87	7.83	10.94	10.89
€$_{2.002}$ PPP adjusted	14.77	12.65	7.11	6.10	9.90	8.48	18.96	16.25	9.14	7.83	12.71	10.89
	***Other* Short distance**						***Other* Long distance**					
	Air		**Bus**		**Car/Train**		**Air**		**Bus**		**Car/Train**	
	Spain	**EU25**	**Spain**	**EU25**	**Spain**	**EU25**	**Spain**	**EU25**	**Spain**	**EU25**	**Spain**	**EU25**
€$_{2.002}$	10.66	10.61	5.13	5.11	7.15	7.11	13.69	13.62	6.59	6.56	9.18	9.13
€$_{2.002}$ PPP adjusted	12.38	10.61	5.96	5.11	8.30	7.11	15.90	13.62	7.66	6.56	10.66	9.13

[*] At factor cost**:** passengers per hour.

Source: Bickel *et al.* (2006).

Table 6.4: **Travel time savings values for freight in Spain ***

	Road		Railway	
	Spain	EU25	Spain	EU25
€$_{2.002}$	2.84	2.98	1.17	1.22
€$_{2.002}$ PPP adjusted	3.30	2.98	1.36	1.22

[*] At factor cost: freight tone-hour.

Source: Bickel *et al.* (2006).

Time savings and problems of capacity

As discussed in Chapter 5, one of the most important elements when valuing and quantifying the changes in time for users with and without the project is determined by the existing capacity constraints. In this sense, to measure accurately the capacity of an infrastructure is a complex issue that involves a detailed technical analysis of each transportation project. Table 6.5 summarizes the units of measurement for each mode of transport and provides indicative values for the maximum capacity of each type of infrastructure.

Table 6.5: **Units of measurement and capacity per modes**

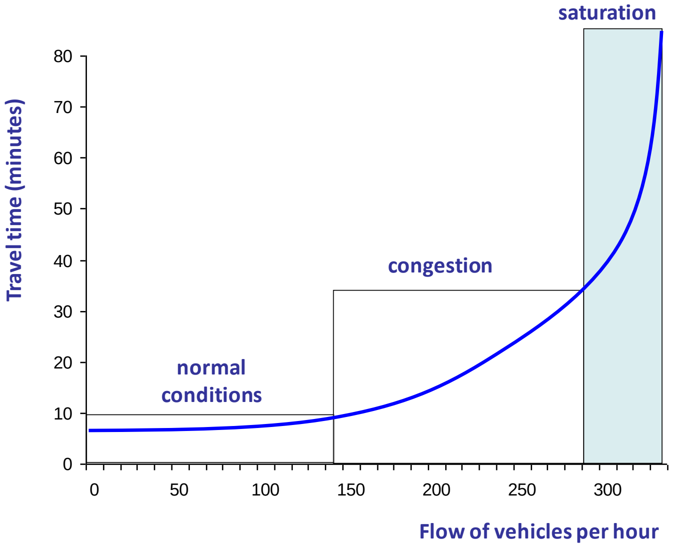
Mode of transport	Type of infrastructure	Unit of measurement	Reference values for maximum capacity
Roads	Conventional	Vehicles per hour. Different types of vehicles are converted into an equivalent in terms of light vehicles (passenger car units)	1200 – 1500 vehicles/hour
	High capacity (highways, motorways)		2000 – 2400 vehicles/hour/lane
Airports	A single runway, length 1200 m IFR aid system	Operations/hour Landings and take-offs including a mix of different aircraft types	35 – 40 op./hour
	Two parallel runways, length > 1300 m IFR aid system		75 – 80 op./hour
Ports	Container terminal, optimal equipment users: containerships of last generation	TEUs/linear meter of berth/year TEU = 20 feet equivalent unit (standardized measure to convert all container sizes)	1500 – 1700 TEUs/m/year
	Dry bulk terminal, users: large vessels	Tons/day	15,000 – 18,000 tons/day
Railway	Electrified line, double track users: mix of passenger and freight trains	Movements/day Volume of operations for each way of train circulation	140 – 150 trains/day/direction

Source: UIC (2004)

Table 6.5 shows that a common feature for all modes of transport is the existence of exponential functional specifications that relate the degree of capacity utilization with the time spent by vehicles or final users (passengers/goods).

Conceptually, it is easy to describe this type of relationship between capacity use and travel time, and traffic flow into three stages: first, when normal conditions prevail (interactions between vehicles or users is minimal); second when congestion problems start to appear and travel times steadily increase; and third, when traffic flows are above some given threshold and travel times dramatically increase. This type of functional specification can be represented by exponential functions as the one represented in Figure 6.1.

Figure 6.1: **Level of service and capacity use**



The existence of this type of relationship between vehicle/hour flows and travel times for users is extremely useful for transport project evaluation, especially when a project adds a significant level of new capacity.

To address the cost-benefit analysis of a transportation project, it is necessary to quantify the time spent by users for different levels of demand in relation to the available capacity. Therefore, these simple functional relationships between capacity utilization and time allow us to obtain information for different scenarios that show us the degree of saturation that an infrastructure can reach in the medium- to long-term. For planning purposes, some of these functional relationships of the type t_{travel} = *f (vehicles flow)* are the following, where *t* represents time and *Q* the number of users:

Conventional roads

Equation: *t=f(veh./hour)*

$$t_{travel} = 6.315 + 0.0046\,Q - 7 \cdot 10^{-6} Q^2 + 4.242 \cdot 10^{-9} Q^3$$

(36.197) (4.477) (-4.520) (6.635) (*t - ratios*)

$R^2 = 0.923$ $F = 311.33$

High capacity roads (highways and motorways)

Equation: *t=f(veh./hour/lane)*

$$t_{travel} = 5.7336 + 0.0005\,Q - 8.46 \cdot 10^{-7} Q^2 + 6.61 \cdot 10^{-10} Q^3$$

(43.332) (0.804) (-1.317) (3.228) (*t - ratios*)

$R^2 = 0.832$ F = 205.11

Airports with a single runway

Equation: t_{delay}*=f(operations/day)*

$$\ln\ t_{delay} = -3.955 + 0.0134\,Q$$

(-11.646) (31.833) (*t - ratios*)

$R^2 = 0.986$ F = 505.26

Container terminals

Equation: $t_{service}$*=f(use of capacity)*

$$t_{service} = t_{ff}\left(1 + 0.15\left(\frac{Q_t}{K_t}\right)^4\right)$$

where $t_{service}$ is the average time spent by containerships berthed (measured in days), t_{ff} is the service time in normal conditions with no congestion (*free-flow time*), K_t is the port terminal capacity in year t (measured in TEUs/year) and Q_t is the effective level of demand (TEUs/year).

Railways

Unlike other modes, there is insufficient empirical work on the railway industry to describe exponential functions (or other specifications of a similar nature) such as those proposed above as a framework to link capacity and time. This gap in the literature on rail capacity is probably because of the nature of the mode in which the need for high coordination between trains that share the same lines for security reasons means that the problem of congestion by the saturation of capacity to be of minor importance compared with other modes of transport. However, the approach based on an exponential function is considered equally valid for this mode of transport, and when evaluating a specific project different capacity scenarios could be simulated trying to relate them to travel times of trains.

6.4. The costs of operation and maintenance

In the evaluation literature, it is common to find formulas that allow the estimation of the values of operation and maintenance costs. Other times, specific values are available for specific cases with different references, such as average costs per mile or per vehicle type. Both the formulas and cost values are a useful and necessary reference for a cost-benefit analysis under uncertainty. Obviously, if specific information is available for the project evaluated, this should be used. If not, the information provided by the formulas and values should be considered a starting point to defining the random variables and the ranges between them.[25]

It is worth noting that road transport provides the greatest number of studies and, consequently, reference values and formulas for both the maintenance and operation of infrastructure and vehicles are available. For illustrative purposes, we present now some of these formulas and values for this mode.

In the Spanish case,[26] it has been suggested the application of the following formulas to estimate the various cost components of vehicles. On inter-urban routes it is recommended to follow the equations linking fuel consumption with road gradient and vehicle speed:

- **Cars on a ramp or level:**

$$C = 117.58 - 1.76V + 1.21 \cdot 10^{-2} V^2 + 24.09p - 0.47Vp + 4.74 \cdot 10^{-3} V^2 p.$$

- **Cars on a slope:**

$$C = 92.76 - 1.3V + 10^{-2} V^2 - 6.77p + 0.33pV - 2.45 \cdot 10^{-3} V^2 p.$$

- **Trucks on a ramp or level (half-loaded):**

$$C = 388.18 - 7.32V + 7 \cdot 10^{-2} V^2 + p[101.28 + 1.99 \cdot 10^{-2} V + 7.85 \cdot 10^{-3} V^2].$$

- **Trucks on a slope (half-loaded):**

$$C = 213.31 - 6.15V + 7.42 \cdot 10^{-2} V^2 + p[6.08 + 3.82 \cdot 10^{-2} V + 7.27 \cdot 10^{-4} V^2].$$

where:

C = fuel consumption per km (cm^3).

V = speed in km/hour.

P = gradient in percentage.

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[25] The working paper "Producer and user costs estimation in transport projects evaluation" presents a review of these components.

[26] See **Ministerio de Fomento (1993)**.

Also for Spain, it is possible to obtain values for the total and distance-related unitary per kilometer costs according to the classification in *Table 6.6.* In the same way, *Table 6.7* presents the total costs and distance-related unitary per kilometer costs in the case of buses and *Table 6.8* shows the values of direct costs and distance-related unitary per kilometer costs for goods transport.

Table 6.6: **Cost categories for buses and goods vehicles**

Direct costs	Time-related costs	Depreciation of the vehicle Financing of the vehicle Drivers Insurances Fiscal costs Expense allowances
	Distance-related costs	Fuel Tyres Maintenance Repairs
Indirect costs*	Structural, commercial and other costs	

* These costs are not mentioned as such in the case of goods vehicles

Source: Ministerio de Fomento (2008a; 2008b).

Table 6.7: **Total (direct and indirect) and distance-related costs for buses in Spain**[*]

Type of bus	Total cost/km	Kilometric cost/km
More than 55 seats	1.51	0.56
From 39 to 55 seats	1.36	0.48
From 26 to 28 seats	1.21	0.38
From 10 to 25 seats	1.07	0.34

[*] Euros 2008.

Source: Ministerio de Fomento (2008a) and authors' calculations.

6.5. The value of a statistical life

A common effect of transport projects is the change in the probability of the number and severity of accidents. For example, removing dangerous points in a road supposes that drivers can make the journey with a lower risk of accidents, resulting in fewer injuries or fatalities. Such changes in the level of risk entail a change in the welfare of individuals that must be incorporated into the evaluation of transport projects.

Table 6.8: **Direct and distance-related costs for freight in Spain**[*]

Type of vehicle	Direct cost		Distance-related cost	
	€ per km travelled	€ per km loaded	€ per km travelled	€ per km loaded
Articulated of general load	1.07	1.26	0.52	0.62
With three axles of general load	0.97	1.14	0.41	0.48
With two axles of general load	0.87	1.02	0.34	0.40
Refrigerated and articulated	1.16	1.36	0.59	0.69
Refrigerated with two axles	1.09	1.45	0.43	0.57
Hazardous materials (chemical) tanker	1.16	1.66	0.50	0.72
Hazardous materials (gases) tanker	1.18	2.35	0.50	1.01
Food products tanker	1.05	1.57	0.50	0.75
Dusty products tanker	1.11	1.55	0.53	0.73
Vehicles carrier (road train)	1.05	1.30	0.54	0.67
Road train	1.03	1.21	0.54	0.63
Articulated container carrier	1.11	1.30	0.53	0.63
Articulated solid bulk dumper truck	1.06	1.32	0.53	0.66
Van	0.91	–	0.17	–

[*] Euros 2008.

Source: Ministerio de Fomento (2008b) and own elaboration.

The monetary valuation of these variations in the level of risk is usually made by analyzing the exchanges that individuals make between small changes in the level of risk and willingness to pay or to be compensated, either in real markets (the most common is the labor market, where individuals agree to take riskier jobs in exchange for a higher salary) or through surveys designed in a hypothetical market. In real markets, the most common procedures are known as hedonic pricing models (or hedonic wage models in the case of the labor markets), whereas in the hypothetical markets any method of valuation based on stated preferences can be applied.

In the case of changes in the risk of suffering a fatal accident, and from these monetary values, it is possible to gain what is known as the **value of a statistical life**. This procedure basically consists of increasing the monetary values previously obtained in a proportion equivalent to that required to transform small changes in risk levels associated to a certain probability of death (probability equal to 1). For example, if individuals were willing, on average, to increase by 1 per 10,000 their risk of death in exchange for 100 Euros per year, implicitly, this would be equivalent to a value of a statistical life of 1 million Euros. It should be noted that this concept of a statistical life is not about assigning a human life value, which of course is priceless, but the change in risk of injury or death that is quantifiable, like any other risk.

From the above it also follows that there is **no unified monetary value for decreases in the risk of accidents**. The willingness to pay for decreases in risk is like the willingness to pay for any other good or service, so that it is expected to differ depending on the characteristics of the individual who expresses his willingness to pay (age, income, etc.), on the characteristics of the risk assessed (e.g. differences in the type of risk according to degree of control, voluntariness, responsibility or fear) and on how such risk affects the individual and is perceived by him. This justifies the diversity of monetary values used in different countries and the different recommendations that each country uses to evaluate transportation projects based on country-specific studies.

In the field of transport projects, this disparity also appears. One study performed a recollection ofanalyzed 30 papers that provided estimates of the value of a statistical life for different countries between 1973 and 2001, obtaining different estimates ranging from less than $200,000 to more than $3 million (at 1997 prices).[27]

This divergence also happens at the institutional level. In the evaluation of transport projects, the Department of Transport from the United States in 2008 quantified the value of a statistical life at $5.8 million, while acknowledging the imprecision of the figure; it also recommended complementary analyses by using $3.2 million and $8.4 million. The monetary value of non-fatal accidents was established, depending on their severity, as a proportion of the monetary value of a statistical life as reflected in *Table 6.9*.

Table 6.9: **Correction factors based on the severity of an accident**

Severity	Proportion of the value of a statistical life
Minor	0.0020
Moderate	0.0155
Serious	0.0575
Severe	0.1875
Critical	0.7625
Fatal	1.0000

Source: DOT (2008).

In the case of European projects, it is worth noting that they tend to use an average value of a statistical life of **€1.5 million** adjusted for the different countries by GDP per capita at purchasing power parity. The monetary values for severe and minor accidents are quantified at 13% and 1% of that figure, respectively.[28]

Along this line, there are also estimates for the Spanish case in which there is an estimate of the monetary value of a statistical life of **1,020,000 Euros** (2002), and **132,000 Euros** and **10,200**

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[27] **de Blaeij *et al*. (2003).**

[28] See **Maibach et al. (2008)** and **Link et al. (2003).**

Euros (2002) for severe and minor non-fatal accidents. Considering all the direct and indirect costs, these figures reach values of 1,122,000, 138,900 and 10,500 Euros, respectively.

However, these estimates are not based on any specific field study developed in Spain. Only one study has estimated the statistical value of a life in Spain from changes in the risk of death in a traffic accident. These authors provided a range between **1** and **2.7 million Euros**, depending on the functional form used.[29]

6.6. Environmental externalities

Following the classification developed in the previous chapter in relation to the identification of environmental externalities associated with transport projects, some general criteria for the valuation and quantification of these are as follows.

Noise

Noise is a negative external effect that occurs during the construction and use of most transport infrastructures. This externality has a negative impact on quality of life, work and recreation, and can even deteriorate human health.

According to a study conducted in several European countries that estimated the annual average WTP of individuals by eliminating the inconvenience caused at home by the noise of road and rail transport, it is possible to distinguish five distinct levels of discomfort (null, light, moderate, high, extreme). The results obtained are reported in *Table 6.10*.

As the authors themselves pointed out, inconsistencies in the estimated values (a higher level of discomfort does not necessarily correspond to a greater willingness to pay) may be due to the limited sample size and the fact that individuals with lower income levels, and thereby less willingeness to pay, tend to be those who live in areas with higher levels of noise.

From these results, they recommend the following values for the European Union:

Table 6.10: **Recommended values at the European level***

Discomfort	Road	Railway
Very high	85	59
High	85	59
Low	37	38
Zero	0	0

* Yearly average WTP in Euros 2005.

Source: Navrud *et al*. (2006)

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[29] **Bickel et al. (2006)** for the monetary value of a statistical life and **Martinez et al. (2004)** for an analysis based on changes in the risk of death.

There is also evidence on the quantification of the monetary value of the impact of certain noise levels per country. *Table 6.11* includes three valuations of the impact of changes in the level of noise in the case of Spain.

Table 6.11: **Central monetary values of the noise impact by mode of transport in Spain**

Loudness	Valuation 1[*]			Valuation 2[**]			Valuation 3[***]		
dB(A)	Road	Railway	Plane	Road	Railway	Plane	Road	Railway	Plane
≥51	7	0	10	9	4	13	15	0	23
≥52	13	0	20	9	5	14	30	0	47
≥53	20	0	31	10	5	15	45	0	70
≥54	26	0	41	11	6	16	60	0	93
≥55	33	0	51	12	6	17	75	0	116
≥56	39	7	61	12	7	18	90	15	140
≥57	46	13	71	13	7	19	105	30	163
≥58	53	20	82	14	8	20	120	45	186
≥59	59	26	92	15	8	20	135	60	210
≥60	66	33	102	16	9	21	150	75	233
≥61	72	39	112	17	9	22	165	90	256
≥62	79	46	122	18	10	23	180	105	280
≥63	86	53	133	19	11	24	195	120	303
≥64	92	59	143	19	11	25	210	135	326
≥65	99	66	153	20	12	26	225	150	349
≥66	105	72	163	21	13	27	240	165	373
≥67	112	79	173	22	13	28	256	180	396
≥68	118	86	184	23	14	29	271	195	419
≥69	125	92	194	24	15	30	286	210	443
≥70	132	99	204	26	16	31	301	225	466
≥71	175	142	251	63	53	68	352	277	526
≥72	186	153	265	69	58	74	372	296	553
≥73	197	164	280	74	63	79	391	316	581
≥74	208	175	295	80	69	84	410	335	609
≥75	219	186	309	85	74	90	430	355	637
≥76	230	197	324	91	79	95	449	374	664
≥77	241	208	338	96	84	100	469	394	692
≥78	252	219	353	102	90	106	488	413	720
≥79	263	230	368	107	95	111	508	433	748
≥80	274	241	382	113	100	116	527	452	775
≥81	285	252	397	119	106	121	547	472	803

[*] 2002 Euros at factor cost per year and exposed person.

Source: Bickel *et al.* (2006).

Note:

- *Valuation 1:* Monetary values that include measurable costs of health effects and the estimated monetary value of the discomfort as recommended by Van den Berg *et al.* (2003).
- *Valuation 2:* Includes quantifiable costs of health effects and the estimated costs of discomfort. The latter are defined according to the valuation reported in Navrud *et al*. (2006).
- *Valuation 3:* Includes the willingness to pay to reduce noise discomfort based on hedonic price studies (**Bickel *et al*., 2003**), and quantifiable costs of health effects.

Air pollution

In addition to effects on quality of life and human health, which manifests itself in morbidity and mortality in extreme cases, air pollution causes other impacts, such as less visible environmental damage (e.g. on buildings, sculptures, etc.) or climatic effects that, in turn, affect a wide range of production and consumption activities. As in the case of noise, for the valuation of such impacts the most recommended approach is to conduct a specific study.

However, the availability of evaluation resources or the urgency to obtain results can force to resort to simplifications in the evaluation process (e.g. reducing the number of pollutants or the impacts to consider, simplifying the estimation of emissions , in their behavior, in the estimation of monetary values, etc.) and the use of estimates from other studies as well.

The main problem posed by extrapolating results from other studies is that the environmental impacts caused by transport projects are largely specific to each site and project studied. The reason for this is that the location affects the conditions and types of traffic and thereby the emissions, which in turn are also affected by weather patterns, terrain and so on in the area. Furthermore, the number of receptors (people, crops, infrastructure, etc.) also depends on the place at which the project is developed.

Table 6.12 lists the recommended values for the monetary valuation of the impacts of air pollution on health that might be relevant to the case of Spain, since the corresponding contingent valuation study was conducted in nine European countries including Spain.

Since the impacts on crops and materials can be measured directly by using market prices, in each case it would suffice to use an adequate dose–response function and the corresponding market prices.

Table 6.12: **Monetary values for the valuation of impacts on human health**

	Monetary values per case*
Days of use of medication or bronchodilator	1
Minor restricted activity days, days of coughing, days with mild and acute respiratory symptoms	38
Medical visits (asthma)	53
Medical visits (respiratory diseases)	75
Medical visits (allergic rhinitis)	75
Working days lost	295
Restricted activity days	130
Hospital admissions for respiratory causes	2000
Hospital admissions for cardiac reasons	2000
Years of life lost due to chronic exposure	40,000
Years of life lost due to acute exposure	60,000
New cases of chronic bronchitis	200,000
Fatal cancer due to radionuclides	1,120,000
Non-fatal cancer due to radionuclides	481,050
Inherited defect due to radionuclides	1,500,000
Value of a death avoided	1,500,000

* 2000 Euros

Source: Preiss and Klotz (2007).

Some authors[30] recommend using the estimated monetary values proposed by HEATCO[31] for pollutants $PM_{2.5}$ and PM_{10}, as it provides different figures for different types of populations, whereas for other pollutants the use of values given by CAFE,[32] since they are more conservative, is suggested. All these values are summarized in *Table 6.13*.

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[30] See **Maibach *et al.* (2008)**.

[31] See **Bickel *et al.* (2006)**.

[32] See **Holland *et al.* (2005)**.

Table 6.13: **Estimated monetary costs of air pollution caused by road and rail transport**[*]

Type of pollutant	Source	Unit	Environment	Value
NO_x	CAFE	Euros 2000 (emissions of 2010)		2600
COVDM	CAFE	Euros 2000 (emissions of 2010)		400
SO_2	CAFE	Euros 2000 (emissions of 2010)		4300
$PM_{2.5}$ (Combustion)	HEATCO	Euros 2000	Urban/Metropolitan[**]	299,600
	UBA transferred to HEATCO	Euros 2000	Urban[***]	96,400
	HEATCO/CAFE	Euros 2000	Unbuilt areas	41,200
PM_{10} (No combustion)	HEATCO	Euros 2000	Urban/Metropolitan[**]	119,900
	HEATCO[****]	Euros 2000	Urban[***]	38,600
	HEATCO	Euros 2000	Unbuilt areas	16,500

[*] Euros 2000 per ton of pollutant.

[**] Urban/Metropolitan: Population with more than half a million inhabitants.

[***] Urban: Areas with less than half a million inhabitants.

[****] Transferred to HEATCO in Maibach *et al*. (2008).

Source: Maibach *et al*. (2008).

Landscape

Transportation projects often lead to the degradation of the scenic or recreational value of the area in which they develop. This type of impact is site-specific and, hence, it is not possible to establish a reference value, making it necessary to study each particular case. The monetary valuation of these impacts is usually performed by the method of the cost of travel and/or by any of the stated preference methods. The cost of travel method allows valuing recreational, cultural, historical or scenic goods as well as their characteristics. However, this procedure is only able to capture the monetary values assigned to the services of the studied area that require people to move there for their enjoyment. In turn, stated preference methods also allow the quantification of monetary values assigned by individuals who have not expressed their preferences by moving to the affected area.

Soil contamination

The environmental impact of soil contamination can have effects on flora and fauna, land productivity and even human health. Moreover, these effects can manifest after several years. This represents an additional complication for their evaluation and inclusion in the application of cost-benefit analysis.

All this complexity motivates its valuation to be usually performed by using some of the techniques based on the cost side: the replacement cost, the avoidance cost or restoration of the environmental good or service. However, such approaches have the disadvantage of ignoring the preferences of individuals and, therefore, consider arbitrary values that might have little relation to the true social values. A more appropriate approach is to identify and quantify the impact of each specific case by using dose–response functions and then to value these effects monetarily through market prices (e.g. in the case of the effect on land productivity) or by using stated or revealed preference methods (e.g. if there are impacts on human health).

Water contamination

Water contamination can cause different effects that might appear later in time and might not be spatially confined to the area of the initial point of contamination. Therefore, it is not possible to establish monetary values of reference, and these situations must be evaluating then on a case-by-case basis.

Water pollution can affect marine and river fauna (and thereby fish production), the relevant ecosystems, agricultural production, the recreational value of natural areas and human health. Given the diversity of effects, its monetary value will require, analogous to the case of soil contamination, a combination of different procedures, using first dose–response functions for the quantification of effects and then market prices and stated or revealed preferences valuation methods.

Climate change

The impact of transport on climate change according to different studies is mainly motivated by the emission of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The valuation of this impact is highly complex because it causes global long-term effects that are diverse in nature (floods, impacts on agriculture, human health effects, changes in precipitation, increase in the probability of the occurrence of natural disasters, etc.), and for which there is usually no accurate knowledge. Therefore, there is great uncertainty in the valuations, and different studies tend to focus on the specific better known effects of climate change.

Empirical evidence provides a recommended range of monetary costs for a limited group of climate change impacts in the short-term (2010–2020), based on various studies that use the avoidance cost method, as well as in the long-term (2030–2050) (*Table 6.14*). The authors justify this decision because in the short-term the uncertainty around the cost of avoidance is smaller since there are policy objectives to reduce emissions that might be associated with particular costs (for 2010 the targets set in Kyoto and for 2020 the reduction in emissions of the European Union of at least 20% compared with 1990, as approved by the European Council in March 2007), whereas for the long-term the political objectives are not yet defined.

Table 6.14: **Ranges of recommended values for the external costs of climate change in Europe**[*]

Year of application	Central values		
	Lower value	Central value	Upper value
2010	7	25	45
2020	17	40	70
2030	22	55	100
2040	22	70	135
2050	20	85	180

[*] Euros per ton of CO_2.

Source: Maibach *et al*. (2008).

Vibrations

In general, and in the case of vibrations, two types of impacts can be distinguished:

- On the one hand, the inconvenience that these vibrations cause to the receptors within their sphere of influence. In this case, this impact might be encompassed by the effects of noise discussed above or could be monetarily valued following a similar methodology, though taking care to avoid the possible double-counting of impacts.
- On the other hand, vibrations can have a negative impact on infrastructure or some productive activities. These effects could be monetarily valued by using market prices.

However, in one case or another, such impacts are not usually monetarily valued in transportation projects, considering implicitly that the number of people affected or the overall impact is not significant.

7. CONCLUDING REMARKS

The objective of this **GUIDE** is to serve as a tool for the evaluation of transportation projects. Although in the recent past there have been serious attempts of economic evaluation, the experience of identifying and measuring the social benefits and costs of transport projects is still scarce in Spain. We are still far away from the consideration of cost-benefit analysis of public investments and policies as a standard procedure with real influence in the process of government decision making.

In the construction of infrastructure, the technological vision and some mystification of the economic impact of public works in the economy predominate. The concept of opportunity cost of public funds is not always internalized in the policy of decisions on public investments, and too often we see how new construction is preferred over the maintenance and preservation of the existing infrastructure, or how, among the alternatives available for the same purpose, the most expensive or the one incorporating the latest technology is often chosen without consideration of its social return.

The lack of conventional economic evaluation is sometimes substituted with the rhetoric of the economic development that investment projects in transport infrastructure have. The qualitative description of the indirect effects and other additional benefits arising from the construction of infrastructure that reduces transport costs takes the place of conventional cost-benefit analysis, where direct and indirect benefits (e.g. intermodal) that are not double-counting are measured.

This **GUIDE** is an evaluation tool aiming to provide information on whether the analyzed projects add value to the economy or, by contrast, whether their costs outweigh their expected benefits. Given the usual limitations of information and uncertainty affecting transportation projects, this **GUIDE** is not intended to accurately estimate the internal rate of return on a project whose life can exceed a 30-year period; however, it is not difficult, in most cases, to distinguish between the "good" from the "bad" projects. With this aim, the risk is incorporated from the beginning of the evaluation in order to work with ranges of values and probabilities of obtaining certain results rather than working with deterministic variables that can provide a false sense of certainty in a world characterized by uncertainty.

The application of a cost-benefit analysis requires some technical preconditions that the evaluator must consider. The application of the methodology contained in this **GUIDE** requires the project to be "small" in the sense that its most significant effects could be limited to the primary market and a few related markets with easily identifiable and significant impacts. Second, there need to be markets for the outputs of the project, or when these markets do not exist there must be techniques available to value them with certain guarantees. Third, it is required the level of uncertainty to be tolerable and the evaluation period must not be excessively long.

There are projects whose costs and benefits are distributed among the population without causing significant equity issues. Other projects asymmetrically benefit or harm depending on the level of income or geographic location. Although the ideal would be to hand an explicit treatment to equity by using social weights for benefits according to the group affected, in most cases this is not a feasible option for the analyst.

When the inclusion in the analysis of the redistributive effects of the project is not possible, an alternative is to identify the relevant groups affected, disaggregating benefits and costs by groups and geographical areas, so that decision-makers can be aware of the distributional implications involved in the project's implementation jointly with the impact on efficiency. In addition to increasing the information available for decision-making, this procedure can also identify who should be compensated and who should contribute, if required, to financing the project.

Along with the incomplete treatment of equity, the practice of economic evaluation usually suffers from two extreme errors that affect environmental impacts. The first one is by omission, when the project does not include them; the second one appears when the attempt to quantify their benefits and costs goes too far. Inevitably, projects must incorporate the effects of difficult quantification, and in this case it is preferable to include a good qualitative description of the impact on the landscape or wildlife associated with the possible construction of an infrastructure than to include the monetary cost of this impact obtained in an environmental valuation exercise that offers no guarantees.

The success of cost-benefit analysis is linked to its role as an aid to decision-making. It is an analytical tool, not an administrative requirement that must be overcome for the project to be approved. When the cost-benefit analysis becomes an administrative requirement, it loses its potential as a tool for public decision-making. Therefore, the challenge is to ensure that the system of incentives associated with the investment evaluation process favors the use of cost-benefit analysis as originally conceived, i.e. as an aid to decision-making in the general interest of society.

The institutional design and use of contracts that promote efficiency cannot be separated from the evaluation process. In general, for the infrastructure policy to benefit the majority of citizens it requires several elements, which despite their simplicity can profoundly affect the impact of the evaluation methodology on the real economy.

First, investment projects must be subject to strict criteria of economic evaluation. The requirement to submit a cost-benefit analysis from a certain volume of investment or significant changes in regulation must be coupled with a guarantee of independence and impartiality of the reports by the separation of the agency proposing the project and the agency evaluating it. Also, the evaluation report should be public and accessible to everyone interested (e.g. it can be published on the website of the Ministry) to facilitate social debate and the provision of new information on the affected social agents.

Second, the institutional framework must avoid the current dissociation between investment and financing decisions. As far as possible, the decision to proceed with a project should be linked to its cost, at least partially, in order to guarantee that the organism, or the regional government behind the project, had incentives to propose socially beneficial projects.

Third, private participation should be encouraged through contracts that divide the risk efficiently and that allow the lowest possible prices for its use or the smallest burden on taxpayers.

Finally, economic evaluation should be accompanied by financial evaluation. The economic evaluation of a project should not be limited to the quantification of social benefits and social costs regardless of the financial results. The financial implications of the different pricing alternatives that a project admits with respect to applicable prices, capacity, quality and so on must accompany the social net present value of the project. The evaluation of alternative pricing structures and the comparison of their impacts on social and financial returns offer useful information in order to reconcile what is socially desirable with what is financially viable.

REFERENCES

Bickel, P., S. Schmid, J. Tervonen, K. Hämekoski, T. Otterström, P. Anton, R. Enei, G. Leone, P. van Donselaar and H. Carmigchelt (2003): "Environmental Marginal Cost Case Studies", Unification of accounts and marginal costs for transport efficiency (UNITE), Deliverable 11.

Bickel, P., R. Friedrich, A. Burgess, P. Fagiani, A. Hunt, G. De Jong, J. Laird, C. Lieb, G. Lindberg, P. Mackie, S. Navrud, T. Odgaard, A. Ricci, J. Shires, L. Tavasszy (2006): "Proposal for Harmonised Guidelines", Developing Harmonised European Approaches for Transport Costing and Project Assessment (HEATCO), Deliverable 5.

De Blaeij, A., R.J.G.M. Florax, P. Rietveld, and E. Verhoef (2003): "The value of statistical life in road safety: A meta-analysis", *Accident analysis and prevention*, 35, 973-986.

Del Bo, C., C. Fiorio and M. Florio, (2009): "Shadow wages for the EU regions", Working Document. DEAS University of Milan.

European Commission (2008): *Guide to Cost Benefit Analysis of investment projects. Structural Funds, Cohesion Fund and Instrument for Pre-Accession*. Final Report. DG Regional Policy.

European Investment Bank (EIB) (2007): *RAILPAG*. European Union. European Investment Bank. Available on: http://www.railpag.org.

Department of Transportation (DOT) (2008): "Treatment of the economic value of a statistical life in departmental analyses", Office of the Assistant Secretary for Transportation Policy.

Flyvbjerg, B. Skamris, M.K. and Buhl, S.L. (2004): "What Causes Cost Overrun in Transport Infrastructure Projects?" *Transport Reviews*, 24 (1), 3-18.

Flyvbjerg, B. (2008): "Curbing Optimism Bias and Strategic Misrepresentation in Planning: Reference Class Forecasting in Practice". *European Planning Studies*, 16, (1), 3-21.

Holland, M., S. Pye, P. Watkiss, B. Droste-Franke, and P. Bickel (2005): "Damages per tonne emission of PM2.5, NH3, SO2, NOx and VOCs from each EU25 Member State (excluding Cyprus) and surrounding seas". Clean Air for Europe (CAFE) Programme.

Inter-American Development Bank (IDB) (2006): *Evaluación económica de proyectos de transporte*.

International Union of Railways (UIC) (2004): "Study on Infrastructure Capacity Reserves for Combined Transport by 2015", Final report.

Link, H, L. Stewart-Ladewig, R. Garcia, M. Herry, N. Sedlacek, R. Tomschy, PRODEC Planning Consultants, O. Betancor, G. Nombela, E. Quinet, D. Schwartz, J.P. Taroux, M. O'Mahony, C. Certan, M. van den Bossche, E. Devillers, H. Boersma, J. Nellthorp, G. Tweddle, T. Sansom and C. Nash (2003). "Pilot Account Results for Austria, Denmark, Spain, France, Ireland, Netherlands and UK". UNITE, Working Funded by 5th Framework RTD Programme. ITS, University of Leeds.

MacDonald (2002): "Review of large public procurement in the UK", HM Treasury, London.

Maibach, M., C. Schreyer, D. Sutter, H.P. van Essen, B.H. Boon, R. Smokers, A. Schroten, C. Doll, B. Pawlowska, and M. Bak (2008): *Handbook on estimation of external costs in the transport sector*, Internalisation Measures and Policies for All external Cost of Transport (IMPACT), Version 1.1 Report Delft.

Martínez, J.E., J.L. Pinto and J. M. Abellán (2004): "El valor estadístico de la vida humana en España", XXIV Jornadas de economía de la salud, El Escorial.

Ministerio de Fomento (1993): Recomendaciones para la evaluación económica, coste-beneficio de estudios y proyectos de carreteras, Spain.

Ministerio de Fomento (2008a): Observatorio de costes del transporte de viajeros en autocar. No. 8.

Ministerio de Fomento (2008b): Observatorio de costes del transporte de mercancías por carretera. July.

Navrud, S., Y. Trædal, A. Hunt, A. Longo, A. Greßmann, C Leon, R Espino, R. Markovits-Somogyi and F. Meszaros (2006): "Economic values for key impacts valued in the Stated Preference surveys", Developing Harmonised European Approaches for Transport Costing and Project Assessment (HEATCO), Deliverable D4.

Organisation for Economic Cooperation and Development (OECD) (1988): *Transport and Environment*, OCDE, Paris.

Preiss, P and V. Klotz (2007): "Description of updated and extended draft tools for the detailed site-dependent assessment of external costs", New Energy Externalities Developments for Sustainability (NEEDS), Technical Paper no. 7.4-Rs 1b.

Van den Berg, M. (*et al.*) (2003): "Valuation of noise", Position paper of the Working Group on Health and Socio-economic Aspects.

Appendix I: DEMAND FORECASTING IN THE EVALUATION OF TRANSPORT PROJECTS

The economic profitability of a transportation project depends largely on the anticipated future demand for the infrastructure or evaluated transport mode. As stated in Chapter 4 of the **GUIDE**, major project benefits are derived from reductions in the time and monetary costs of travel for existing users and an increased willingness to pay for the new travelers induced by the project. It is, therefore, essential to have a reliable method for the prediction of demand in situations with and without project.

Demand forecasting requires the availability of a model that explains the behavior of individuals in relation to the major determinants of demand. Generally speaking, demand depends, on the one hand, on a set of socioeconomic and demographic factors and, on the other, on the generalized cost of the evaluated transport mode and the alternatives. In general, the temporal evolution of the first group of variables, including income per capita, population, employment and foreign trade, does not depend on the characteristics of the project, whereas the generalized cost, in terms of travel time and monetary cost, is influenced by the implementation of the project.

The model of demand must take into account all possible users' reactions to a change in costs. When a project involves significant changes in the supply of transport, it is necessary to predict how individuals respond in terms of their increased frequency of travel as well as changes of route, mode and, in some cases, destination. Other projects have little impact on the relative costs of transport modes and are only necessary to determine route changes and the increased frequency of existing traffic. The complexity of the model depends critically on the size of the investment or policy to be evaluated and on the available data.

Countries such as the UK, Holland, Denmark and Germany have developed multimodal national models that allow an evaluation of the effect on demand of transport policies. These models offer an excellent framework for comparing the results of demand models developed to evaluate specific projects.

The following sections discuss, in this order, the main elements that should be included in a demand model, the most appropriate econometric techniques, how to incorporate uncertainty in long-term predictions and, finally, a brief reference to the available models in Spain. Some final remarks close the Appendix.

I.1. Model of demand

A preliminary step in the specification of the model is to correctly determine the geographical area affected by the project. It is well known that the impact of an infrastructure on traffic goes beyond the region directly affected and generates spillover effects on neighboring areas.

A second issue to be addressed is whether we estimate a multimodal or unimodal model. The multimodal model is more complete, although it is also much more complex and demanding in terms of the required information. Therefore, it is less common and generally used in contexts with a strong interrelation between different modes of transport. The unimodal model has the advantage of allowing richer information in the variables included in the equation of demand and, therefore, it captures more accurately changes in the transport network.

Third, it is necessary to determine what type of individual decisions will be affected by the project. Investment in transport, to the extent that it reduces the cost of a journey, changes any of the following decisions: generation of new trips, destination choice, mode choice, route choice and day and time of travel. In the transport demand literature, these decisions are grouped into the well-known stages of generation, distribution, modal choice and allocation to the network. Moreover, when considered appropriately during the evaluation of the project, each of the previous decisions or steps can be segmented according to the day or time of travel.

The generation model estimates the increase in the number of trips as a result of a generalized cost reduction. These trips are driven by both new users and an increased frequency of travel by existing ones. In past decades, the usual convention in the CBA was that the number of trips was fixed and its growth depended only on socioeconomic variables. However, since the nineties, the hypothesis about the inelasticity of demand with respect to costs has been refuted.[33] Currently, the generation model must take into account the socioeconomic variables and the generalized cost of travel after the investment. A substantial improvement in accessibility can generate a significant number of new trips.

Furthermore, in the long-term it is possible that improvements in accessibility encourage changes in the location of businesses and residences, resulting in a greater number of trips on the network and a redistribution of the origins and destinations. The prediction of generated traffic associated with changes in the location requires a model linking land use and transportation. These are complex models with a low degree of standardization. In these cases, prudence in the evaluation advises us to compare the results of the estimation with the effects observed in comparable projects.

The trip destination choice depends on a wide range of variables, including the cost of transport. However, the relevance of this variable depends on the purpose of the travel and the characteristics of the individual. For example, in trips to work or to visit relatives, the destination is fixed, at least in the short- to medium-term. Therefore, it is desirable to estimate the distribution of origin–destination trips with individual data. However, it is unusual to have sufficiently representative origin–destination matrices with disaggregated data. The difficulty of estimation and the consequent possibility of errors explain that this stage is often excluded from the model of demand.

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[33] See, for instance, Goodwin (1996), Noland (2001) and Yao and Morikawa (2005).

Modal choice models have a long tradition in transport economics. The relative costs between modes of transport are the main determinant of modal split. In general, the cost of time has a greater effect than monetary cost. Sometimes it is necessary to include variables such as the frequency or reliability of the service. Hence, part of the market share that the high-speed rail captures from the plane is explained in terms of greater time reliability.

Transport demand tends to have wide fluctuations in time and generate large differences between peak and off-peak periods that alter travel costs. In peak periods, congestion appears and prices are usually higher. In these cases, the modeling of demand segmenting by time periods allows us to better capture individual behavior. However, information costs greatly increase. Furthermore, the prediction over the years of the project should consider the possibility of demand exchanges between slots. The key question is whether the evaluation requires distinguishing demand forecast by periods.

The demand model is closed with regard to the allocation of trips to the network. The allocation model considers the decision of choosing a particular route on a network and calculates the cost of that route. These costs, at the same time, are an input at various stages in the process of demand modeling. This is an iterative process between the model of demand and supply until an equilibrium is reached.

The allocation model allows the incorporation of the costs of congestion, which appears as road traffic increases, to the evaluation of the project. The non-consideration of infrastructure congestion can lead to demand overpredictions as time passes. The modeling of congestion costs must be consistent with the capacity measure used to calculate user costs, as detailed in section 5.3 of this manual. Increased congestion affects not only roads but also railways, airports or any other mode of public transport. The assumption of fixed costs is clearly questionable in the situation without project in which there are no planned improvements in capacity.

The incorporation of the allocation model is a complicated task. In fact, a common assumption in its evaluation is that the generalized cost remains constant over the years of the project. However, ignoring the maximum capacity of an infrastructure or a transport mode can generate significant errors when assessing the net benefits of a project.[34]

There are different approaches to incorporate the choice of route depending on the mode and context of travel with varying degrees of complexity. In general, allocation models in intercity routes are simpler than those needed to model the traffic in urban and metropolitan areas. The transportation network must be defined in the same units as the demand model. Thus, if the trip generation is defined in terms of time, allocation to the route must also be in terms of time. In models where demand is segmented according to time schedule, the definition of the transport network is more complex since it requires cost matrices for each estimation period. The more

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[34] See, for instance, Mackie (1996).

details the more difficult the determination of the equilibrium will be. Therefore, disaggregation decisions must be taken with caution and in accordance with the requirements of the problem and the quality of available data.

When it is not possible to have an allocation model the working paper **"Predicting the demand: uncertainty analysis and prediction models in Spain"** provides a simpler alternative consisting of incorporating a maximum capacity constraint to the functional form of the model. In this approach, *ceteris paribus*, the growth rate of demand decreases as traffic approaches full capacity.

Another aspect to consider is the breakdown of demand by type of passenger or goods. To the extent that the evaluation of a project uses different values of time depending on the user, it will be necessary to segment the demand in accordance with the same criterion.

For evaluation purposes, as detailed in ***Chapter 5***, the estimated demand model should enable a distinction between existing traffic before the investment and the traffic generated by it. The latter includes the traffic diverted from other transport modes or routes and the generation of new trips as a result of cost reductions resulting from investment. The diverted traffic is obtained directly from the modal choice model. Regarding the generation of new trips, in the dynamic context of growth of traffic it is difficult to distinguish between trips arising as a result of the economic growth of those resulting from the reduction in the generalized cost. A good specification of the generation model that includes both economic/demographic factors and the generalized cost of the transport mode – basically time, price and quality – is essential.

Once the different stages of the demand model have been estimated, it is necessary to predict its evolution for the duration of the project. Since the future value of the explanatory variables are not known, a preliminary step is to predict their evolution for the same time period, which introduces a strong element of uncertainty in forecasting demand. It is, therefore, advisable to choose with caution the explanatory variables at each stage of the demand model.

I.2. Traffic prediction models

This section provides a brief review of the available econometric techniques for the estimation and prediction of transport demand.[35] In particular, we focus on models of traffic generation and modal choice. Choosing the most appropriate approach will depend primarily on the nature and magnitude of the project and the availability and/or costs of obtaining the necessary data.

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[35] A more detailed version is in the working paper **"Forecast demand: Uncertainty Analysis and predictive models in Spain."**

The trend model

The trend or naive model is the simplest way to predict since it does not incorporate information on other variables of an economic nature. Obviously, this model only shows the evolution of the existing demand and, in any case, allows incorporating induced traffic. There are various mathematical expressions to relate time to the variable that is to be predicted. Two simple and frequently used alternatives are the linear and semi-logarithmic relationships. The first implies that the rate of change of travel decreases as “t” increases, whereas the second implies a constant rate of change. The prediction based on the extrapolation of a past trend is a common method, though often too simple. This method assumes that past behavior will continue in the future, an assumption that might be overly naive.

The econometric regression model

Transport demand depends essentially on the generalized cost and socioeconomic and demographic characteristics of the population. Econometric models of demand are a suitable methodology for making predictions. Explanatory variables are chosen according to the type of demand to be predicted and the available data. The usual approach is a regression equation estimated with aggregate data in which demand depends on variables related to the socioeconomic and demographic environment – population, employment, GDP or foreign trade volume – and the generalized cost of the use of infrastructure, price and time. The estimation can be carried out with time -series data, cross-section data or panel data.

In order to make long-term predictions it is advisable to use time series data. These data take into account the fact that individuals do not adjust immediately to changes in supply. However, when the series are not stationary, we must be careful with the econometric estimation to avoid spurious regressions. It is advisable to work with annual data and a temporary period of not less than 30 years. The use of quarterly or monthly data is an easy way to increase the number of observations. However, it worth noting that although moving from annual data to quarterly or monthly data implies to multiply the sample size by 4 or 12, the information content of the data is not multiplied by the same factor. This is so because the variability of the sample remains essentially the same, since the variability added when moving from annual data to monthly or quarterly data mainly come from the seasonality, a magnitude generally irrelevant in long-term predictions.

However, when the investment model requires analyzing the specific effects of traffic generation on specific territorial areas (e.g. the opening of a new station), cross-sectional data can provide better predictions. These types of data, because they extend the number of observations and increase the variability of the explanatory variables, can help improve the performance of the estimate. The cross-sectional information might correspond to trips between pairs of origins and destinations within a geographic area, or to aggregate data for different territorial units observed in a given year.

Panel data combine the advantages of both types of information. A panel data consists of cross-sectional units observed for two or more time periods. Its attractiveness is high. First, the sample size and the degrees of freedom of the estimation increase; second, the number of explanatory variables available increase; and usually, since the variation between cross-section units is superior to the temporal variation, it reduces the variance of the estimates and increases their reliability.

The modal choice model

The investment in a particular mode of transport decreases the generalized cost in relation to other sustitutive modes and, consequently, some individuals change to the selected alternative. In some cases, trips diverted from other modes account for up to 40% of new demand.

To the extent possible, it is advisable to estimate a demand equation that allows us to determine how the individual responds to changes in the price and quality of transportation alternatives. It is, therefore, necessary to define a rigorous equation that models the individuals' choices among transportation alternatives.

In this context, discrete choice models provide the appropriate estimation framework. These models have a long tradition in transport economics and show a high degree of accuracy in estimating demand elasticities with respect to the main attributes of transport modes. The use of microeconomic data avoids aggregation biases when individuals are not sufficiently homogeneous. In binary contexts, logit and probit specifications are the most common and their estimations do not offer any major problems. On the contrary, when the choice is made between three or more alternatives, econometric estimation can be complex.[36] The data to estimate these models can come either from the actual observation of individual choices (revealed preferences) or from experiments based on hypothetical decisions (stated preferences).

However, discrete choice models suffer from two disadvantages. On the one hand, they require having a micro database with a high sample size that contains all the characteristics of transport modes for each of the individuals in the sample. On the other hand, they are not exempt from difficulties predicting aggregated traffic flows.[37] Thus, these models predict the probability that an individual in the sample chooses a particular alternative. However, for evaluation purposes we are interested in the aggregated volume of diverted trips. It is, therefore, necessary to define an aggregation procedure. Provided that the sample is sufficiently representative, the best way to proceed is to aggregate the individuals that comprise the sample.

A possible alternative to discrete choice is to estimate a regression with aggregate data in which the dependent variable is the utilization rate (or frequency) of a certain mode of transportation

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[36] For a detailed analysis, see Train (2003).

[37] See Ortuzar and Willumsen (2001).

(logistic equation). This approach can be valid if the project affects traffic flows that behave sufficiently similar to the aggregate data available, and it has been applied in several studies. This type of equation is estimated with cross-section data, since the market share of an alternative has little variability over time.

It should be noted that in both cases the goal is to obtain the diverted demand. Thus, the implicit assumption in these models is that total demand is fixed and, consequently, the elasticities are lower than those obtained in contexts that allow traffic generation or suppression.

I.3. Forecast from recommended values and elasticities

In some circumstances, it is difficult to obtain adequate data to conduct a sufficiently robust estimate of a demand function. Some examples of this are the prediction of demand for a new transport mode or changes in the location of activities as a result of investment. This could be the case of the construction of a new metropolitan rail network, the building of a new airport in a city or a new link from one port to the rail network. The estimation difficulties result in estimation errors in prediction. In these cases, an alternative option is to rely on the reported results of similar projects in other geographical areas. Gathering information about the effects that certain investments have had on traffic is an alternative way to approach understanding the impact on the generation of new trips and on the modal shift. For example, the available evidence for the construction of high-speed railway lines has shown that approximately 30% of demand comes from planes, 20% from cars and 30% is new generated traffic.[38] In investments in the road network, the evidence shows a traffic generation of around 15%.

The incorporation of the information contained in previous reference studies can be done by using the estimated elasticity. Elasticity is a mathematical concept that measures the response of demand to marginal changes in explanatory variables. In transport economics, there is ample empirical evidence about values on the elasticity of demand for the main explanatory variables. This ample evidence grants credibility to the values found and thereby to its application for estimating results derived from changes in the supply of transport.[39] Since each transport project has specific characteristics, it is necessary to choose elasticities estimated in studies with similar characteristics. The specific context in which demand has to be predicted will determine what kind of elasticity is most appropriate.

However, a warning is necessary regarding the use of elasticities to evaluate changes in demand resulting from a transportation project. Since elasticity is calculated for marginal changes in one

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[38] See King, 1996; Hensher, 1997; de Rus and Roman, 2006; Vickerman, 1997.

[39] The working paper **"Forecasting demand in project evaluation"** provides empirical evidence for elasticities; in particular, it offers elasticity values for the investments in high-speed rail and road infrastructures and empirical evidence for this elasticity.

variable, this value cannot be maintained when evaluating transport investments that generate significant discrete changes in the cost of transport.

I.4. Uncertainty in demand forecasting

Although in the past decades the quality of the models that estimate transport demand has improved significantly, prediction errors seem to persist. A recent study by **Flyvbjerg *et al*. (2006)** concluded that uncertainty in predictions has not improved over time. Errors in the prediction of demand can have serious consequences in the evaluation. An overly optimistic forecast will result in an excess of capacity, whereas if the actual demand exceeds the predicted one congestion problems will arise. In the case of infrastructure, errors will have greater consequences since investment costs are virtually irreversible.

Flyvbjerg *et al*. (2006) reviewed 210 investment projects and found that in 50% of examined road investment projects the difference between the estimated traffic and actual traffic was observed to be ± 20%. In addition, sometimes there was a systematic bias towards overpredictions. This is the case for investment in railway infrastructures (**Flyvbjerg *et al*., 2006; Pickrell, 1989**) or toll motorways (**Bain, 2009**). The predicted demand in rail transport in some projects was two-thirds higher than that observed and in 85% of the analyzed projects traffic was predicted to be more than 20% higher than that actually observed. In most studies, bias appears at the modal distribution stage, which is overly optimistic about the ability of railways and toll highways to capture a share of demand. In all predictions, the high estimated standard deviation shows a high degree of uncertainty and risk.

A brief review of some informative studies for investment projects in toll roads and motorways in Spain shows that the same trends can be observed in our country. In this sense, **Vassallo and Baeza (2007)**, after analyzing the financial plans of various concession companies, conclude that they have tended to overpredict traffic, in particular, they find that predicted traffic for the first year of operation of the Radial 2, Radial 4, Radial 3, Radial 5 and the new access to Barajas Airport in Madrid was particularly high, being overestimated by between 58% and 66%.

Given that uncertainty is, at least partially, inevitable, it is advisable to consider methods that allow incorporating it into the evaluation. The most usual way to deal with uncertainty is to present alternative estimates under different scenarios for the explanatory variables of demand. However, this solution does not recognize all sources of uncertainty and provides no information about the likelihood of each scenario.

Without abandoning the demand estimation models, the econometric methodology allows itself incorporating the uncertainty in the predictions. There are three sources of uncertainty. The first, uncertainty in the inputs, comes from our ignorance of the future values of the explanatory variables. The second is the uncertainty associated with the random disturbance of the model that, among other things, reflects the combined influence of possibly omitted variables in the model; and the last, uncertainty in coefficient estimates, is derived from the use of estimates of population parameters of the model rather than their actual values. The sum of the last two groups might be called the uncertainty in the model. A common way to incorporate these uncertainties into the prediction is through stochastic simulation techniques, using various procedures such as **bootstrapping** methods. This allows us to offer a probability distribution of demand for each of the years predicted and not just the expected value, as usual. This methodology was applied in two case studies analyzed in this project.

I.5. Forecasting demand models in Spain

The Public Administration organisms with competence in transportation have developed different models to estimate and predict demand. These are unimodal models and, in general, aim to predict the medium- and long-term aggregate demand from socioeconomic variables.

Puertos del Estado uses time series models to predict the evolution of the Spanish port system traffic by type of product, type of movement and port. In addition, they also try to predict the evolution of the macroeconomic scenario, with a model of input–output tables for each good sector in terms of gross value added and foreign trade. These data are obtained from surveys to shippers in which quantitative (projected traffic, transport chain) and qualitative (quality level expected, modal selection criteria) information is collected. The results are broken down into foreign and coastal shipping and loading and unloading operations for 9 sectors and 40 products. The predictions obtained are subject to convergence criteria to ensure global consistency, and competitive factors and coefficients of attraction between ports are analyzed in order to derive a method of distribution are also analysed.

The *Dirección General de Carreteras* has a traffic prediction model by large corridors based on time series extrapolations. The model includes in four stages the prediction of registrations by type of vehicle, the estimation of the number of vehicles and traffic in each year by age and type of vehicle and the fuel consumption.

For air transport, AENA makes long-term projections of demand in terms of passengers and aircrafts, cargo, passengers per hour on arrivals and departures and aircraft and aircraft per hour on arrivals and departures. The prediction is made by using an econometric model that uses demographic variables, tourism indicators, microeconomic variables (elasticities, maintenance costs, taxes, fuel prices, etc.) and macroeconomic variables that are clustered in GDP. The prediction incorporates changes in the supply of transport (new airport or entry into operation of the HSR, for example). This long-term model is completed with short-term predictions incorporating information from leading companies, routes, types of passengers, fleet, etc. The predictions are subject to consultation with each airport and a panel of experts. The paper "**Predicting the demand: uncertainty analysis and prediction models in Spain**" presents a more detailed discussion of the methodologies used.

Available models provide a suitable baseline against which to compare predictions made in the evaluation of a project. Additionally, they constitute a basic starting point to know the main explanatory variables of demand for each mode of transport. However, in general, they are not designed to evaluate the impact of a transport policy or project.

First, to the extent that they are unimodal models, they are not useful for evaluating the impact of policies that affect to more than one transport alternative or that significantly alter the cost or quality of one of them so that the demand of alternative sustitutives changes. That is, it is not possible to quantify the modal shift. Second, existing models do not incorporate the generalized cost of travel, making it impossible to contemplate the generation of new demand as a result of reducing such cost. It is true that for projects involving small changes in generalized cost it would be possible to apply the corresponding average values of demand elasticities to predict the demand according to the future behavior of socioeconomic variables. However, this approach is not appropriate when evaluating projects that modify the ratio of relative costs, such as opening a high-speed railway line or a new airport runway.

In general, the available models are too aggregated to be applied to a specific project or transport policy.

According to the discussion in this Appendix, it is necessary to move towards the construction of more comprehensive demand models that include the generation of new trips, the change in the matrix of origin–destination and the change in the modal distribution resulting from a change in the generalized cost of travel. This requires the creation of a comprehensive database and homogenization of the assumptions underlying the different models available today. Since a model, like a map, is only a simplified representation of reality and in this simplification lays its utility, there is no single methodology applicable to all projects. The type of modeling must be adapted to the purpose of the project, in the same way as if we consult a map to answer a question (find a country or locate a street in a city) which we wish to respond. This question will determine the type of information to use.

I.6. Conclusions and recommendations

The prediction of transport demand for evaluation is certainly complex and subject to many decisions. It is, however, an essential task that requires the maximum attention to succeed in project selection.

An important part of this complexity stems from the fact that any mode of transport operates as a network and from the existence of the relationships of substitutability and complementarity between alternatives. Hence, any investment has consequences not only on its own demand, but also on the demand for the rest of the routes and competitive modes. These consequences are specific to each type of investment and there are no general rules that can be applied.

Available econometric models to forecast demand have a long tradition in the transport economics literature and make good predictions provided certain conditions are met. First, it is necessary to have appropriate databases for the type of prediction. Sometimes, it is indispensable to carry out surveys to supplement the information available. The need for information extends to the characterization of the network in terms of generalized cost to allow for the interaction of supply and demand and avoid traffic allocations that are not feasible. Second, we must choose the appropriate model for each project. Third, when the difficulties of using a predictive model are insurmountable, we should trust in the result observed in projects of similar characteristics to avoid overly optimistic predictions. Finally, the prediction of demand must quantify the uncertainty associated to each result and incorporate it into the final evaluation.

I.7. References

Bain, R. (2009): “Error and optimism bias in toll road traffic forecasts”, *Transportation*, 36, 469–482.

De Rus, G. and C. Román (2006): “Análisis económico de la línea de alta velocidad Madrid-Barcelona”, *Revista de Economía Aplicada*, 42, 35-80.

Flyvbjerg, B., M. Skamris and S. Buhl (2006): “Inaccuracy in Traffic Forecasts”. *Transport Reviews*, 26 (1), 1-24.

Goodwin, P.B. (1996): “Empirical evidence on induced traffic, a review and synthesis”, *Transportation*, 23, 35-54.

Hensher, D.A. (1997): “A Practical Approach to Identifying the Market Potential for High-Speed Rail: A Case Study in the Sydney-Canberra Corridor”, *Transportation Research A*, 31 (6), 431-446.

King, J.(1996): “Economic significance of high speed rail”, Proceedings of the 17th Australasian Transport Research Forum.

Mackie, P. (1996): “Induced traffic and economic appraisal”, *Transportation*, 23 (1), 103-119.

Noland, R.B. (2001): “Relationships between highway capacity and induced vehicle travel”, *Transportation Research A*, 35 (1), 47-72.

Ortuzar, J.D. and L.G. Willumsen (2001): *Modelling Transport*, 3rd edition, John Wiley & Sons, Chichester.

Pickrell, D. (1989): *Urban rail transit projects: forecast versus actual ridership and costs, Urban Mass Transportation Administration*, US Dpt. of Transportation, Washington DC.

Train, K.E. (2003): *Discrete choice methods with simulation*, 2nd edition, Cambridge University Press, UK.

Vassallo, J. and M. Baeza (2007): “Why traffic forecasts in PPP contracts are often overestimated?”, Research Paper, EIB University Research Sponsorship Programme. European Investment Bank, Luxembourg.

Vickerman, R. (1997): “High-speed rail in Europe: experience and issues for future development”, *The Annals of Regional Science*, 31 (1), 21-38.

Yao, E. and T. Morikawa (2005): “A study of an integrated intercity travel demand model”, *Transportation Research A*, 39 (4), 367-381.

Appendix II: THE VALUATION OF EXTERNAL EFFECTS IN PROJECT EVALUATION

The methods of the economic valuation of the external effects of transportation projects play a key role in the process of evaluating them. Its purpose is to allow the direct incorporation into the cost-benefit analysis of those impacts caused by a project and not considered by the market. However, for the application of these techniques it becomes necessary to resort to various assumptions and simplifications that are briefly presented in this **Appendix**.

Therefore, monetary estimates of the impacts should not ever be taken as an exact value, having some caution at the time of their inclusion in the study. This increased caution may be accomplished, for example, by providing confidence intervals or probability distributions of the estimates. In this way, it would be possible to conduct a sensitivity analysis on the influence of these estimates in the decision about the appropriateness of undertaking a project. Another option would be to calculate what the economic value of these impacts would have to be for the net present value, or any other indicator, to be zero, and compare this value with the estimates of these impacts obtained by using economic valuation techniques.

II.1. The economic value of external effects

In very general terms, the economic value of a good can be defined on the basis of what individuals are willing to pay for it, which ultimately takes us to their preferences. In the case of the costs or benefits of a project involving goods and services sold in a market, the decisions that individuals make in that market can serve as a clue to explore their preferences for these goods and services and thereby quantify monetarily the impact. In the case of costs and benefits where there is no market, it is necessary to seek alternative means to help revealing their preferences. These methods are the focus of this section.

These techniques are based on different assumptions and represent different ways of approaching the preferences of individuals. Therefore, not all the techniques can be used for the measurement of any impact, and it is necessary to consider each situation and what we want to value at the time to choose one or another technique. Sometimes it might be necessary to use several techniques simultaneously in order for each to pick up a different aspect or type of value and thereby be able to quantify the full monetary impact.

The mentioned techniques are usually classified into two groups: techniques based on related markets and techniques based on hypothetical markets.

II.2. Techniques based on related markets

These techniques obtain the preferences of individuals for non-tradable goods and services by the consideration of the decisions they make in the market of other goods and services that have some kind of relationship (of substitutability or complementarity) with those of the non-market.

This idea shows that this group of techniques can only monetarily quantify those impacts resulting from a project on the use that individuals make of non-market goods and services. Within this group we can distinguish three types of methods or procedures: the method of deviant behavior, travel cost method and hedonic price method.

Method of deviant behavior

This method is based on the idea that individuals can compensate for changes in the quantity or quality of a non-market good or service through changes in the quantity or quality of market goods and services, thereby maintaining their standard of living or utility unchanged. Following this idea, and assuming a ratio of perfect substitutability and other additional hypotheses (**Mäler, 1974**), the individual willingness to pay for a marginal change in the quantity or quality of a non-tradable good or service affected by a project can be expressed as the expenditure marginal change for the private good or service.

Examples of this type of behavior can be found in expenses that households make to better insulate their home from outside noise when the level of noise increases or expenses for buying bottled water, purchase filtering tools and/or construct private wells to offset declines in the quality of water supply.

Despite its conceptual attractiveness, this method presents, however, a number of caveats. The following are some of them. First, this procedure does not apply to non-marginal changes. The benefit of a non-marginal change for the non-tradable good or service q is quantified monetarily, according to this procedure, as the reduction in the spending in the private good z that makes the individual retain the current level of utility. However, given that they have more resources due to the improvement in q, individuals will increase their consumptions of goods and services, including the good z. Thus, the reduction in the expenditure for good z will be less than that necessary to maintain the utility level constant and, therefore, it will underestimate the benefit derived from the change in q. Second, this method assumes that individuals adjust rapidly to changes in q, when they might in reality need some time. Finally, deviant behavior cannot completely offset a decline in q or lead to other benefits.

Travel Cost Method (TCM)

This method is based on analyzing the relationship of complementarity between a non-market good or service (in this case leisure, cultural, historical or scenic goods that require a trip by the individual for their enjoyment) and a private good (the trip). This complementary relationship implies that the enjoyment of a non-market good or service (e.g. visiting a natural landscape) requires the use of a private good (the trip), so it is possible to indirectly capture the preferences of individuals for using that non-tradable good or service.

The idea behind this method is that the costs that people incur for visiting a site can be interpreted in some cases as a "price" for accessing the site and, therefore, can be used to estimate the WTP of individuals for services provided by the site.

The TCM allows estimating both the economic value of places and the economic values of specific characteristics, or changes in the quality of places.

Estimating the economic value of recreational services of a place

For the first objective, the two most common variants of the TCM are the zonal or aggregated method and the individual method (**Bateman, 1993**). The zonal TCM consists of establishing a relationship through a regression of the rates of visits to a site from different geographical areas of origin (usually expressed as number of visits per 1000 inhabitants of the area concerned in a period of time) with the cost in which they incur when traveling from each zone of origin to the site considered. The estimation of this function involves the implicit assumption that individuals living in different areas have identical preferences regarding the site and, hence, if they face the same costs of transport they would carry out the same number of visits. The individual TCM is conceptually similar to the zonal one; however, the relationship between the number of visits (per unit of time) and the cost of travel is set at the individual level. When calculating these expressions we might also include other explanatory variables (at the individual level in the individual TCM and aggregated in the zonal TCM) that could influence the number of visits.

From these travel functions it is possible to approximate[40] the net welfare obtained by individuals when visiting a site. To do this, we simply have to calculate the areas situated below these functions.

In the case of the zonal TCM, the area under the function between the cost of visits and the cost for which the visitation rate is zero provides an approximation of the net welfare for individuals from that zone when visiting that area. For example, assuming a linear function relating visitation rates (V/N) to travel costs (C), this area would be the area represented by the triangle CAB in Figure II.1. This area reflects the difference between the cost of visiting the place for the individual and what the individual would be willing to pay as a maximum, with the result a surplus for the consumer. It would be a welfare lost if the individual cannot visit the site. This amount is then divided by the average of visits in Zone 3 and multiplied by the total number of visits to the area to approximate the net welfare derived from all Zone 3 visits. Proceeding similarly for all areas and summing the values obtained in each approximation it is possible to obtain the net welfare derived from all site visits in the period under examination.

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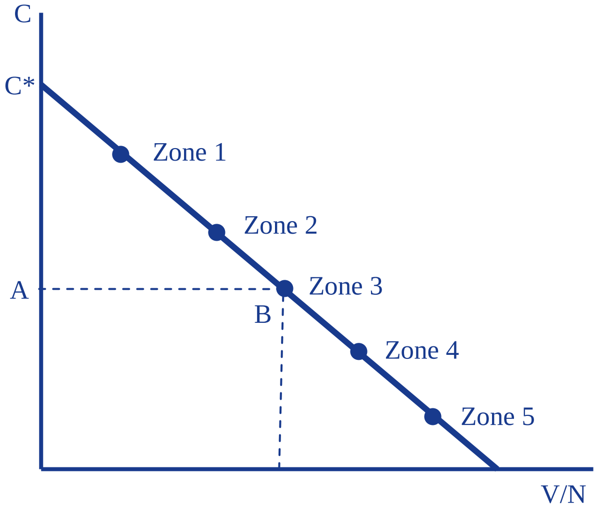
[40] The values obtained are an approximation to the concept of economic value contained in Section 2 (**Creel and Loomis, 1991**).

Figure II.1: **The Zonal TCM**



Similarly, in the case of the individual TCM we would calculate the area under the function and the travel costs incurred by the individual in order to obtain a monetary approach to the net welfare that the individual gains from trips made to the site. Several authors have derived expressions that allow for the calculation of the net welfare for different specifications of the functional form (see, for example, **Bockstael and Strand, 1987**). For example, in the case of a linear function $V = a + bC$, the estimated value of the net welfare of the individual would be $\frac{(V(C_0))^2}{-2b}$ where C_0 is the cost of the journey for the individual. To obtain the net welfare of all visits to the site over a period of time we should add all visitors.

So far, monetary estimations obtained with the zonal and individual TCM correspond to the complete recreational experience. That is, the individual welfare derived from the travel and the time on the site. For the net welfare derived exclusively from the stay on the site, it has to be calculated what would happen to the rate of visits or the number of visits to the site when different prices to enter the place are set. For that purpose the assumption that visitors react to increases in entry prices in the same way as they react to increases in travel costs is made. The result is a demand curve stating that the number of visits depends on different entry prices. The area under this curve provides an approximation to the net consumer welfare derived from the experience on the site.

However, some authors have opted for different procedures to distinguish how much of the welfare derived from the trip is attributable to the stay on the site. For example, one option is to ask individuals directly how much of their enjoyment can be assigned to the stay on the site and how much to travel. This information can be used to adjust the travel costs or might be introduced directly as a variable in the travel function.

From the above it follows that the application of the individual and zonal TCM is not exempt of difficulties. Among them, for example, are the calculation of travel costs (and especially the monetary quantification of the cost of time spent in travel), the inclusion in the analysis of alternative sites, the allocation of travel costs when the individual visits more than a site or how to analyze jointly individuals performing site visits of different lengths.

Estimating the economic value of changes in the characteristics of a site

When the main objective is the economic valuation of changes in the characteristics of a site, rather than the recreational services provided by the site as a whole, the most widely used approximation of the TCM is based on random utility models (RUM). This variant (**Haab and McConnell, 2002; Bockstael and McConnell, 2007**) is also most appropriate when there are sites that can be considered as alternatives to the one being evaluated.

This approach analyzes the choice of an individual on whether or not to travel, and if they decide to travel the individual's decision about which site to visit. It is a probabilistic approach that considers that the probability for an individual visiting a site depends on the utility (welfare) they gain by visiting that place, which is in turn dependent on travel costs and site characteristics.

Hedonic Price Method (HPM)

The hedonic price theory was initially formulated by **Rosen (1974)** based on the alternative to neoclassical consumer theory raised by **Lancaster (1966)**, whereby a class of differentiated products can be fully described based on a series of objectively measurable characteristics. In this way, goods and services are made up of a number of attributes and characteristics and their prices reflect these differences.

The hedonic model is frequently applied to various markets such as the housing market, but it is also possible to extend its use to others such as the labor market or the car market, where the good has significant characteristics that influence the market price.

In the case of, let us say, a car, there is a basic model to which we can add a number of extra characteristics. Each extra option will involve an additional payment, so thereby it is easy to discern what the price paid for each attribute is. However, when goods and services have a dimension that is not traded in the market, it is difficult to establish what the price of this non-market attribute in itself is, since it is inserted into the total price. In this case, the observed prices, together with the levels of various attributes, tradable and non-tradable, contained in each good or service can help ascertain a measure of the implicit value that consumers place on each attribute that forms the good or service, including non-market attributes.

This approach is similar to the TCM method explained above, since both are based on a complementary relationship between a market good or service and a non-market good or service. However, both differ in that the HPM operates through changes in prices of private goods rather than through changes in their quantities (number of trips) as it happens with the TCM. In the HPM, the private good or service is not acquired to enjoy the non-market one; instead, it is one of the characteristics of that good.

The equilibrium relationship between the price of the good P and its vector of characteristics Z is called the hedonic pricing function:[41]

$$P = h(Z)$$

The partial derivative of this function with respect to any characteristic (e.g. Z_i) gives its marginal implicit price $\partial h / \partial Z_i$, i.e. the additional expenditure required to achieve a marginal change in the characteristic. In a competitive market, the marginal implicit price will equal the WTP of individuals for the marginal change in that feature (**Freeman, 1993**).

Since not all individuals have the same preferences for Z_i, the next step is to estimate a function that explains how this marginal WTP varies with Z_i, the socioeconomic characteristics of individuals and any other variable that can reflect preferences. From this function it is possible, under certain assumptions, to approximate the economic value for an individual of non-marginal changes in the level of the characteristic Z_i by simply calculating the area under this function, the horizontal axis and the two vertical lines passing through the initial and final values of Z_i. However, it should be noted that, given the difficulties, most empirical studies do not perform this second stage (**Pearce and Turner, 1990**).

The HPM has several problems. On the one hand, from a theoretical point of view, its validity rests largely on the assumptions of perfect information, the perfect mobility of consumers and the existence of equilibrium in the considered market. These assumptions are hardly verified in reality. On the other, from a practical standpoint, the problems that may occur are also numerous. For example, the omission in the hedonic price function of a relevant variable can lead to biased estimates of the coefficients of the other variables or the variables included in the analysis can present problems of multicollinearity (**Hanley and Spash, 1993**).

II.3. Techniques based on hypothetical markets

These are all the techniques that in order to reveal consumer preferences, and thereby their WTP or willingness to accept (WTA), are based on fictitious markets designed through surveys. Therefore, unlike the techniques based on related markets, the estimates are not derived from the observed behavior of individuals; instead their behavior is inferred according to the answers that they provide in a survey.

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[41] To estimate the hedonic price function, various functional forms can be adopted (Taylor, 2003).

Since they are not based on an observed behavior and, therefore, not linked to the use of the good or service being valued, this group of techniques is the only one capable of capturing non-use values (i.e. the values that individuals assign to a good or service even when they are not users of it) as well as use values. For example, an individual can express his WTP for the preservation of an animal species threatened with extinction even without having any intention of going to see the animal in its habitat.

At first, these methods seem extremely simple, we simply ask the individual to make choices that serve to infer their WTP or WTA for a hypothetical change and assume that they will answer exactly what they are asked. The problem arises precisely from this last assumption, because hypothetical questions can tend to produce hypothetical answers.

Therefore, in this group of techniques survey design is of great importance. Given that a questionnaire is what allows extracting the individual preferences about the change being valued, it must be made in such a way that individuals perceive the questions as real issues, minimizing possible biases and the existence of strategic behavior on the part of respondents (**Mitchell and Carson, 1989**). Usually the design of a good questionnaire needs a long time, requiring testing in small groups and small samples of the total population before achieving a final version.

The questionnaire is usually structured in three parts:

- The first part is intended to introduce the person to the good or service being valued and makes them think about their preferences of it.
- The central part is dedicated to the valuation. In this part, we must present to the respondent in a clear and concise manner the election they are going to do, capturing any aspects that might affect their decision. Subsequently, the valuation issues designed to gain their WTP or WTA for the proposed change are included.
- Finally, the third part includes questions aimed at obtaining information on the characteristics or attitudes of respondents. The values obtained in valuation issues can be compared with these data to test consistency. In addition, these questions can also be used to extrapolate the results obtained in the valuation survey to the population.

Methods based on hypothetical markets can be classified into two groups: *the contingent valuation method*, with its many variants, and *multi-attribute methods* (**Hanley *et al.*, 2001**). They both represent two different ideas of the valuation process. The first focuses on the holistic nature of the goods or services to be valued, whereas the latter pays more attention to the attributes that define them. This different conception of the evaluation process is manifested mainly in the format of the questions of valuation and the type of information obtained.

Contingent valuation method (CVM)

In the contingent valuation exercise, individuals are offered a given change in consideration to a certain amount of money, and then the process of exchange the individual performs between both is analyzed.

The formats of the questions are very different (**Mitchell and Carson, 1989**). Perhaps the most direct one is the so-called open format, that is to ask directly for the WTP or WTA of individuals for the change studied. These responses can be analyzed simply by calculating the arithmetic mean or by estimating through regression methods functions explaining the declared WTP or WTA from other variables (e.g. socioeconomic). The main disadvantage of this approach is that it places individuals in an unusual position. In reality, individuals have to decide between a set of goods and services with different price sets. They are rarely faced with situations in which they are asked to make an offer that can be accepted or rejected by the seller. As a result, surveys using this format provide high non-response rates and high proportions of implausible extreme values (high or low), and thereby high variance in the valuations.

In the simple dichotomous format, subsamples of individuals are asked whether they would be willing to pay for the provision of a public good, varying the amount of such payment among the various subsamples. Thus, the possible answers are normally restricted to closed categories *yes, no, or do not know/do not answer*. From these responses an estimate of the probability function of the individuals' responses can be obtained using parametric (typically logit or probit), semi-parametric or nonparametric methods, from which the average or median of the variable maximum WTP is normally calculated as a measure of the welfare change.[42]

The simple dichotomous format has the advantage of its simplicity and that the respondent is faced with a purchase proposal to which they are familiar: accept or not accept the good by paying that amount of money or do not. In addition, with the dichotomous format much fewer *protest* and *does not know* responses are obtained as well as values that are less dispersed than with the open format (**Mitchell and Carson, 1989**). As **Carson and Grove (2007)** pointed out, the simple dichotomous format can be interpreted by individuals as a referendum and, therefore, can be considered incentive compatible. This concept refers to the theoretical property of this preference elicitation format that no individual can improve, with any combination, acting strategically and reporting a value that is different from the real one. All other elicitation formats do not have this property, although this does not necessarily mean that individuals realize they are responding to a format that is incentive compatible, and take advantage of it by intentionally providing answers that do not correspond to their real preferences.

From these two basic formats (open and simple dichotomous) other formats that are just variations or combinations of both are derived, seeking to extract more information from the individual.

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[42] The analysis of these responses is based on random utility models (see **Hanemann and Kanninen, 1999**).

Thus, in the double dichotomous format the respondent is asked whether they would pay a certain amount of money to acquire a certain good. If the answer is yes, then they are prompted for an amount slightly higher (lower, if the answer is no). Thus, regardless of non-responses, it is possible to get four types of responses: *yes-yes, no-no, yes-no and no-yes*. The problem with this approach is that the responses to the second payment can be influenced by the proposed payment in the first step (called starting point bias). Moreover, as **DeShazo (2000)** pointed out, the responses to the first payment can sometimes be inconsistent with the responses to the second.

The auction format continues this process until reaching a change from *yes* to *no* (or from *no* to *yes*). In this format, the individual is asked if they would pay a certain amount for the goods or services concerned. If the answer is affirmative, the question is repeated using a higher price until the response is negative. The highest price with an affirmative response is interpreted as the maximum WTP. To obtain the minimum WTA, the same iterative process in reverse would take place. As in the previous case, an objection frequently made to this type of format is the influence that the initial offer could have on the individual ratings, because this initial value can be taken by the interviewees as a "shortcut" to get his decision and not reveal the true value. Another disadvantage is that, although open questions can be made by mail or in person, this type of question can only arise in face-to-face or computer interviews. However, the responses provided by this format often have a low standard deviation around the mean in relation to the previous type and a smaller number of non-responses.

Another format sometimes used is the mixed format, which consists of two successive questions: the first closed and the second open. That is, there is an initial "hint" to which the individual responds with an acceptance or rejection of the suggested price and then the maximum WTP is asked. This measure shares some problems with the auction format because the price given as a reference can influence responses and also shares some advantages of the dichotomous format with respect to the open format.

Models based on multi-attribute choices

In this group of techniques, individuals have to express their preferences on sets of alternatives defined by attributes that vary at different levels.

The attributes that define the alternatives in this group of techniques are motivated by the aim of the study. The researcher has to include as attributes the most important elements that can be considered by individuals when making their decisions in the area studied (**Alpert, 1971**). It is precisely the change in the values of these attributes what is the focus of economic valuation in these techniques. For this purpose it is necessary that one of the attributes reflects a monetary payment. The number of attributes and their levels should not be too high for respondents so they do not have difficulties in assimilating the information provided. Successive pre-tests and pilot tests are necessary when designing the survey to verify that the population considers that the attributes and levels included are relevant and easily understood.

After selecting the attributes and levels, these are combined to obtain the different alternatives. The simplest way is known as full factorial design, which consists of generating all possible alternatives based on the levels of the attributes considered. Subsequently, these alternatives are randomly grouped into sets, making sure that in the groups there are no alternatives that can be better or worse in all attributes compared with other alternatives in the same group. This type of design allows the estimation of both main effects and interactions. A main effect is the direct effect of an attribute considered individually. In a main effects model, the effect of an attribute would be the same irrespective of the other attributes. The interactions involve two or more attributes. In a model with interactions, the effect of an attribute is different for different levels of another attribute. With a full factorial design, all main effects and all interactions of second order and higher order can be estimated and are not correlated.

The disadvantage of a full factorial design is that such designs are only applicable to small designs that use a low number of attributes, or levels, or both, which is not the case for most applications. The reason is that, except in those cases, the number of alternatives generated by the full factorial design is very high and, therefore, the monetary cost and the risk of fatigue of individuals to respond to the survey is also very high. For example, in a design with five attributes and four levels each one we will get 4^5, i.e. 1,024 different alternatives.

This problem is solved by using fractional factorial designs. These designs involve the selection by a specific procedure of a particular sample or set of the full factorial design alternatives, so that the intended effect can be estimated in the most efficient manner. The drawback is that all these designs generally involve some loss of information, assuming that the effects of interactions between two or more attributes are zero or insignificant.

Once the choice sets are elaborated, one or more of these sets of alternatives are presented to individuals to express their preferences. The type of choice task that individuals have to perform on the set of alternatives presented depends on the specific method applied for obtaining preferences. The most common ones are contingent choice (**Louviere *et al*., 2000**) and contingent ranking (**Chapman and Staelin, 1982; Hausman and Ruud, 1987; Ben-Akiva *et al*., 1992; Foster and Mourato, 2002**).

In a choice experiment, the individual must choose their preferred alternative from among those submitted, which must include an alternative representing the current situation or status quo. This format of choice is easy to answer for individuals as it reminds them, to some extent, of the kinds of tasks they must perform in real markets. However, from the point of view of the researcher, this variant provides less information per set of choice and individual. In a contingent ranking exercise, individuals have to order all alternatives included in the choice set according to their preferences. This format provides more information than a choice experiment, but it raises doubts about the ability of individuals to provide reliable answers when the number of alternatives included in the choice set is high, when individuals have similar preferences on alternatives or when some alternatives that individuals would never choose or do not know properly are included in the alternative choice set (**Louviere *et al*., 2000**). For these reasons some authors do not recommend using all the information derived from a full contingent ranking of all individual alternatives included in the choice set (**Chapman and Staelin, 1982, Ben-Akiva *et al*., 1992, Louviere *et al*., 2000**).

The analysis of the responses provided by individuals in both cases is based on the RUM. It is assumed that individuals receive a utility from each alternative and select those alternatives that provide greater utility. The utility U_{ni} derived by an individual *n* from alternative *i* is divided into a deterministic component V_{ni} , which reflects the influence of the levels of the attributes present in that alternative, and a random component ε_{ni} . This stochastic component contains all the factors that are unobserved or ignored by the researcher.

For example, assuming that the deterministic component takes a linear form, we obtain:

$$U_{nj} = \beta_n ' x_{nj} + \varepsilon_{nj} ,$$

where x_{nj} is a vector containing the levels of attributes for alternative *j* presented to individual *n* and β_i is a vector of parameters that represents the contribution of each attribute to the value perceived by the individual. The objective is to estimate these parameters of the utility function.

According to the assumptions made on the distributions of these stochastic components and their relationships with the random components of the other alternatives included in the choice set, the model to be applied to estimate the parameters of the utility function will vary (**Louviere *et al*., 2000**). For example, if one assumes that the random components are independent and identically distributed according to a distribution of extreme value type 1, in the choice experiment a multinomial logit model is obtained, while in the contingent ranking an ordered logit model is obtained.

Once the parameters are estimated, it is possible to calculate the WTP of individuals to marginal changes in the levels of attributes. Simply the change in the utility function between the attribute of interest and the attribute reflecting a monetary payment has to be estimated. For example, in the case mentioned earlier of a linear utility function, the WTP for a marginal change of an attribute is the ratio, with the opposite sign, between the coefficient of that attribute in the utility function and the coefficient of the attribute that represents the payment.

Finally, if the values of non-marginal changes in one or more attributes simultaneously need to be estimated, a simplified approach is to assume that the estimated marginal values are constant for all units and attributes, and then add those values in a linear fashion (**Hanley *et al*., 1998**). More formally correct procedures can be found in **Hanemann (1982)**.

II.4. References

Alpert, M. (1971): “Identification of determinant attributes: a comparison of methods”, *Journal of Marketing Research*, VIII, 184-191.

Bateman, I. (1993): “Valuation of the environment, methods and techniques: revealed preference methods”, en R. K. Turner (ed.), *Sustainable Environmental Economics and Management*, Belhaven Press, London, UK..

Ben-Akiva, M., T. Morikawa and F. Shiroishi (1992): “Analysis of the reliability of preference ranking Data”, *Journal of Business Research*, 24 (2), 149-164.

Bockstael, N.E. and K. E. McConnell (2007): *Environmental and resource valuation with revealed preferences. A theoretical guide to empirical models*, Springer, Dordrecht, Netherlands.

Bockstael, N. E. and I.E. Strand (1987): “The effect of common sources of regression error on benefit estimates”, *Land Economics*, 63 (1), 11-20.

Carson, R. T. and T. Grove (2007): “Incentive and informational properties of preference questions”, *Environmental and Resource Economics*, 37 (1), 181–210.

Chapman, R. G. and R. Staelin (1982): “Exploiting rank ordered choice set data within the stochastic utility model”, *Journal of Marketing Research*, 19, 288-301.

Creel, M. D. and J. B. Loomis (1991): “Confidence intervals for welfare measures with application to a problem of truncated counts”, *Review of Economics and Statistics*, 73 (2), 370-373.

DeShazo, J. R. (2000): “Designing transactions without framing effects in iterative question formats”, Mimeograph, School of Public Policy and Social Research, University of California, Los Angeles, United States.

Foster, V. and S. Mourato (2002): “Testing for consistency in contingent ranking experiments”, *Journal of Environmental Economics and Management*, 44 (2), 309-328.

Freeman, A. (1993): *The measurement of environmental and resource values: theory and methods*, Resources for the Future, Washington D. C., United States.

Haab, T. C. and K. E. McConnell (2002): *Valuing environmental and natural resources: the econometrics of nonmarket valuation*, Edward Elgar, Northampton, MA, United States.

Hanemann, W. M. (1982): “Applied welfare analysis with qualitative response models”, CUDARE Working Papers, no. 241, University of California, Berkeley.

Hanemann, W. M. and B. Kanninen (1999): “The statistical analysis of discrete-response CV data”, I. Bateman and K. Willis (eds.), *Valuing environmental preferences: theory and practice of the contingent valuation method in the US, EC, and developing countries*, Oxford University Press, Oxford, UK.

Hanley, N. and C. Spash (1993): *Cost-Benefit analysis and the environment*, Edward Elgar Publishing Limited, Aldershot, UK.

Hanley, N., R. E. Wright and V. Adamowicz (1998): “Using Choice Experiments to Value the Environment. Design Issues, Current Experience and Future Prospects”, *Environmental and Resource Economics* 11(3), 413–428.

Hanley, N., S. Mourato and R. E. Wright (2001): “Choice modelling approaches: a superior alternative for environmental valuation?”, *Journal of Economic Surveys*, 15(3), 435-462.

Hausman, J. A. and P.A. Ruud (1987): “Specifying and testing econometrics models for rank-ordered data”, *Journal of Econometrics*, 34 (1-2), 83-104.

Lancaster, K. J. (1966): “A new approach to consumer theory”, *The Journal of Political Economy*, 74, 132-157.

Louviere, J. J., D. A. Hensher and J. D. Swait (2000): *Stated choice methods: analysis and applications*, Cambridge University Press, Cambridge, UK.

Mäler, K-G. (1974): *Environmental economics: A theoretical inquiry*, The Johns Hopkins University Press, Baltimore, United States.

Mitchell, R. C. and R. T. Carson (1989): *Using surveys to value public goods: the contingent valuation method*, Resources for the Future, Washington D. C., United States.

Pearce, D. and R. Turner (1990): *Economics of natural resources and the environment*, Harvester Wheatsheaf Edt, Hertfordshire, UK.

Rosen, S. (1974): “Hedonic prices and implicit markets: product differentiation in pure competition”, *Journal of Political Economy*, 82 (1), 34-55.

Taylor, L. (2003): “The hedonic method”, en K.J. Boyle and T.C. Brown (eds.), *A Primer on Nonmarket Valuation*, Kluwer Academic Publishing, London, UK..

Appendix III: EQUITY AND TERRITORIAL IMPACTS IN PROJECT EVALUATION

Most public investment projects consciously or unconsciously provoke redistribution impacts affecting the set of agents in society. Distributional equity refers to the project's impact on the net available income and on agents' wealth in real terms. Furthermore, in the case of investment projects in transport infrastructure it is common to find heterogeneous spatial effects that benefit some regional areas over others. We will refer to the latter case as impacts on spatial equity.

The use and enjoyment of non-renewable resources by the current generation will positively or negatively affect the potential for future generations. This effect is stronger depending on the life of the investment, the use of non-renewable resources and the existence of harmful and irreversible impacts on the environment. One way to consider this impact on intergenerational equity is through the discount rate. However, there is no consensus on how to adjust this.

Any investment project in transport infrastructure causes some agents to be benefited more than others. This difference can be more or less pronounced, but it is practically impossible that it disappears. In every society, it is possible that different socioeconomic groups have strong preferences for different modes of transport. A simple study of transport demand would identify the different groups of users and the potential benefits that such investment could bring them. In this sense, the investment in a particular mode of transport also favors a particular socioeconomic group.

The decision to invest in transport infrastructure is usually a compromise between efficiency and equity. In cases in which efficiency and equity do not go together, the decision depends on the decision-maker preferences for one or the other. Given the extremely subjective nature of this decision, the tools designed to assist in the decision-making process and project choice cannot provide optimal or definitive solutions. Instead, they seek to provide mechanisms to guide the decision-making process, but without judging to what extent certain projects are preferable to others.

III.1. Distributional equity

The success of the project, in terms of equity, depends largely on the system's ability to redistribute income from benefited to disadvantaged groups. The main controversy arises with this task. It is possible that one of the objectives of the project is precisely to contribute to this redistribution of wealth. The redistribution can be regressive or progressive, depending on whether the beneficiaries belong to groups with higher incomes or vice versa. For this purpose a function that weighs the benefits and costs obtained in the cost-benefit analysis by socioeconomic or income groups is built.

The traditional cost-benefit analysis does not weight different groups and, therefore, unwittingly or not, considers the same weight for all. However, for many years there has been the belief that the social value provided by an additional Euro to an individual with a high income level must be less than that obtained by an individual with a lower income (**Harberger, 1984**). According to this criterion, individuals with a lower income should be given a greater weight in the model of cost-benefit analysis than that applied to individuals with higher incomes. However, this practice has been questioned from a theoretical point of view (**Harberger, 1984**) and an empirical point of view, for example, from the World Bank, which no longer uses any weights in the cost-benefit analysis (**Devarajan *et al., Squire and Suthiwart-Narueput,* 1995)**. The main theoretical reason, as **Harberger (1978)** pointed out, is based on the risk of accepting inefficient project implementations, not based on the utility of the project itself, but to meet the criterion of inequality among different income groups. The latter case would be undesirable because the project would achieve a redistribution of income that could be achieved at a lower cost through the use of other fiscal mechanisms.

In practice, as discussed by **Devarajan *et al., Squire and Suthiwart-Narueput,* 1995 (1995)**, the use of distributional weights is subjective, and the technicians responsible for their evaluation do not feel comfortable in deciding between one weighting function and another. Another drawback is the enormous effort in time needed to identify the benefits of each of the groups. These two reasons, together with the aforementioned inefficiency, cast doubt on the use of distributional weights.

III.2. Spatial equity

The choice of the location and route of the transport infrastructure determines which geographical areas will benefit from the investment, at least in the near future. Again, the criteria of efficiency and equity might not be compatible; however, in this case, the impact on social welfare is not as intuitive as in the case of distributional equity. In this sense, the national investment strategy to increase efficiency and equity is not obvious **(Puga, 2002)**.

One option to try to understand this dilemma is to use models of economic geography. The implications of the investment in transport infrastructure, translated into a reduction in transport costs, depend on labor market mobility, wage regulation, market structure, the degree of specialization in production and differences in degrees of development between regions, as well as the type of infrastructure to implement. The result of this policy can affect the location of firms and workers and thereby the growth of certain geographical areas. These population movements can lead to a greater concentration or a greater spread of the population into space. It has been shown that an increase in concentration leads to increases in productivity, but also that a spatial diversity of the population favors innovation and production expertise by geographical area **(Duranton and Puga, 2001)**.

Labor market mobility is a key ingredient for understanding the consequences of reduced transport costs. If market mobility is perfect, **Krugman (1991)** anticipated that once transport costs fall below a certain threshold, the expectation is that the whole industry should be concentrated in a single region. However, if labor mobility is imperfect, as it is in the case of Spain, the industrial concentration causes an excess of unsatisfied labor demand, causing an increase in wages and, therefore, that part of the industry would prefer locating in areas where labor is cheaper **(Krugman and Venables, 1995)**.

Although a new or improved transport link between a developed region and a less developed one can be beneficial for both, it is also possible that the latter region would need to undergo a process of adaptation to a more competitive environment. High transport costs are a natural barrier to trade and this can benefit the local industry. The ability and necessity of this region to adapt to the new environment and find new alternatives that more efficiently redirect its manufacturing sector will be the key factor to hoping that the investment in transport infrastructure will benefit or not such regions.

The type of transport infrastructure implemented greatly affects the service and production sectors. While a highway construction has a greater impact on the location of productive firms, a line of high-speed railway favors the concentration of businesses services and headquarters in the largest cities **(Duranton and Puga, 2001)**. **Vives (2001)** confirmed the hypothesis that in Spain there has been a tendency to spatially concentrate the economic power to a greater extent than that conducted by the economic activity, and that a high-speed line between a capital and an industrial city promotes the relocation of many headquarters that move to the capital.

III.3. Equity evaluation methods in transport infrastructure projects

The wide range of transport infrastructure projects and the different availability of information make it impossible to develop a unique method of universal application. The purpose of this section is the exposure of methods that allow quantifying the change in equity between the *situation with project* and *without project*. When developing equity indicators it should be noted that the results differ if the starting point is not restricted to the mentioned comparison. The *partial indicator* of equity refers to the differences in equity between the situation without project and with project among areas or groups regardless of the starting point. The *joint indicator* of equity takes into account the initial situation and how it is altered with the implementation of the project. The use of one type of indicator or another depends on the objective and the decision-maker's preferences in relation to equity. For example, if the objective of the decision-maker is to accept projects that do not alter the current equilibrium in terms of equity, the use of partial equity indicators is sufficient. However, if the objective is to reduce the existing differences in equity, the employment of joint equity indicators is necessary.

Hedonic price method

One way to identify which agents and how much they benefit from a public investment in transport infrastructure is through the revaluation of assets such as housing, offices, commercial premises or land. The HPM can capture, through revealed preferences, the market value of the new infrastructure.

An investment in transport infrastructure that benefits a particular area causes an increase in demand, both in the buying/selling market and in the rental market. It is, therefore, expected to see an increase not only in property prices but also in rental prices. The latter effect can cause tenants with higher willingness to pay to wish to move to this area and then generate an upward pressure on rents, displacing some of the current tenants. Therefore, in this context it is possible that the main beneficiaries of the investment would be the owners of real estate assets and not all the area residents. This finding reinforces the use of the hedonic price method as an indicator of the impacts on equity.

The aim of the hedonic price method, within the framework of the impact of the implementation of transport infrastructure, is to identify a parameter that relates an infrastructure improvement to an increase in the price of real estate assets. For this it is necessary to consider a broad set of variables that simultaneously condition the final price of the asset using a weighting scheme and that is statistically significant. Once this link is estimated, it is possible to perform simulations such as "what would happen if..." investment is made and who would be its beneficiaries and to what extent by geographical area.

CBA-dependent methods

The information used in the method of surpluses, if available, can be helpful when assessing the equity impacts of the project. The variation in social welfare can be decomposed (see Chapter 4) into:

$$\Delta SW = \Delta CS + \Delta PS + \Delta GS + \Delta RSS$$

This classification allows us to obtain a first distribution of social welfare by interest groups. From these distributions it is possible to obtain ratios that collect the relative benefit of some groups relative to others. In this way, $k_{CS,PS}$ can be interpreted as an inequality indicator between the profits made by some groups and others. This indicator can be used as complementary information to that offered by the CBA.

There are two forms of incorporating them into the analysis. One possibility is to consider them as an additional criterion to that provided by cost-benefit analysis. Thus, the decision-maker will consider among the various alternatives which one or ones meet their preferences in terms of equity and efficiency simultaneously. A second possibility is to use them as comparable values with reference values set *ex ante* and that represent restrictions in relation to the maximum allowed inequality. In this sense, these indicators serve as decision rules or barriers that projects need to pass to be approved, in relation to equity. Once the projects that meet this restriction are filtered, the next step is to choose the one that offers a better performance in terms of other criteria such as the criterion of cost-benefit analysis.

Although this information is not always available, it might be possible to break down the increase in social welfare directed to consumers by socioeconomic group. A source of information for this purpose can come from previous studies on the use of infrastructure by individual socioeconomic groups, either in the study area or other areas where a similar distribution is expected. Similarly, from this information it is possible to produce ratios that represent the relationship in which socioeconomic group *i* benefits from the project in relation to another socioeconomic group *j*:

$$k_{i,j} = \frac{\Delta CS_i}{\Delta CS_j} \quad \forall i, j \in G \ .$$

Examples of decision rules can be:

- Ranges or valid intervals for the indicator, e.g.: $k_{CS,PS} \in [1,4]$.
- Equivalence relationships, for example by imposing a progressive condition such that: $1 < k_{12} < k_{13} < k_{14}$.

Other methods of evaluation together with a further discussion of the methods presented in this Appendix can be found in the working paper **"The impact of transport infrastructure projects on spatial and distributional equity."**

Joint evaluation methods

The aim of this type of evaluation is to analyze the impact on equity by using as a starting point the current situation without the project and how it might be altered by the implementation of it. In this sense, the decision-maker's objective function is complex because it incorporates explicitly the trade-off between efficiency and equity.

To date, three methods have been the most accepted: multicriteria methods, indexes of spatial need and industrial location models.

The main objective of cost-benefit analysis is to provide a single monetary value (or its probability distribution) that allows the decision-maker to choose among different investments or accept a certain one. However, there are certain aspects, mostly related to the impacts on the environment and equity, that can hardly be translated into a monetary value. In the case of significant impacts, this deficiency can be supplemented by using *multicriteria methods*. These methods try to value multiple criteria simultaneously through three types of procedures: those based on utility functions, mathematical programming and ordering methods (outranking). Applications of this type of methodology have been carried out to assess road networks (see, **for example, Torrieri *et al*., 2002**) or the expansion of airports (see, for example, **Vreeker *et al*., 2001**). These methods can be of great help, but are not without limitations; among them, it is complex to establish a weighting criteria system that is not subjective from the point of view of the analyst, and this might call the results into question.

The *index of spatial need* combines two types of indexes: an index of potential need, according to various criteria such as population, income level and transport utilization, and an index of accessibility to transport infrastructure.

In particular, the proportion of residents of an area *i* who have access to public transport is calculated. Then, thresholds are set for these indicators to discern the relative need of each geographical area. In cases where both indicators are below the minimum acceptable, it is understood that these are areas of high priority. Finally, through a geographic information analysis it is possible to distinguish the most deprived areas, which do not necessarily coincide with those with a reduced transport infrastructure since this assessment takes into account the level of population and accessibility simultaneously.

The objective of the *industrial location model* is to determine the role of accessibility to transport infrastructure for the industries in their location decisions. From this information, it is possible to simulate how much they would be willing to pay for those improvements in accessibility, providing information that can be broken down by geographic area. The econometric method used is a multinomial logit model where the endogenous variable is the expected profit for being located in a region *j* and the exogenous variables are the economies of location (concentration index of the industry), urbanization economies (Herfindahl index), the quality and availability of interregional infrastructure in relation to major business centers (GIS map with road transport times), local infrastructure (electricity), stock of human capital in the region and the region's natural conditions.

According to this model, changes in the expected profit for being located in a region can be calculated by using the estimated parameter of the model. It is a model with many similarities to that of hedonic prices. The main difference is that industrial location models can cover a wider geographic spectrum than the hedonic price method, but in turn are limited to evaluating the impact on firms, ignoring the effects on families. This latter issue can be an advantage or a disadvantage depending on the type of project being analyzed.

III.4. References

Devarajan, S., L. Squire and S. Suthiwart-Narueput (1995): "Reviving project appraisal at the World Bank", PRD Research Paper No. 1496, The World Bank, Washington, D.C.

Duranton, G. and D. Puga (2001): "Nursery cities: Urban diversity, process innovation, and the life cycle of products", *American Economic Review*, 91(5), 1454-1477.

Harberger, A.C. (1978): "On the use of distributional weights in social cost-benefit analysis", *The Journal of Political Economy*, 86 (2), 87-120.

Harberger, A.C. (1984): "Basic needs versus distributional weights in social cost-benefit analysis", *Economic Development and Cultural Change*, 32 (3), 455-474.

Krugman, P. (1991): "Increasing returns and economic geography", *Journal of Political Economy*, 99 (3), 483-499.

Krugman, P. and A.J. Venables (1995): "Globalization and the inequality of nations", *Quarterly Journal of Economics*, 110 (4), 857-880.

Puga, D. (2002): "European regional policies in light of recent location theories", *Journal of Economic Geography*, 2 (4), 373-406.

Torrieri, F., P. Nijkamp and R. Vreeker (2002): "A decision support system for assessing alternative projects for the design of a new road network", *International Journal of Management and Decision-Making*, 3 (2), 114-138.

Vives, X. (2001): "Globalización y localización de la actividad económica: Cataluña y la geografía del poder económico", en T. García-Milá (ed.), *Nuevas fronteras de la política económica 2000*, CREI, Universitat Pompeu Fabra, Barcelona.

Vreeker, R., P.T. Nijkamp and C. Ter Welle (2001): "A multicriteria decision support methodology for evaluation airport expansion plans", *Transportation Research D*, 7, 27-47.

Appendix IV. INSTITUTIONAL DESIGN AND PROJECT EVALUATION

The construction, maintenance and operation of transport infrastructure imply, in general, the interaction of many economic agents with different degrees of information and interests. In the context of asymmetric information and conflicting objectives, the evaluation of a transportation project should not be analyzed through a conventional cost-benefit analysis. On the contrary, the existence of information asymmetries and conflicts of interest require a different approach taking into account explicitly the institutional context and the incentives that different types of contracts and financing mechanisms have on the agents involved.

In general, in all transportation projects it is possible to distinguish two stages. The first stage is related to the institutional design in which the funds needed to carry out a project in a particular region are allocated. Therefore, the agents involved in this first stage are, on the one hand, the national government, and, on the other hand, regional governments.[43] Once the funds needed to carry out the transportation project are obtained, the regional government must, in a second stage, select the concessionaire companies and design the contracts to be used in the construction, maintenance and operation of the infrastructure. Therefore, economic agents involved in the second stage are the regional governments and the concessionaire companies.

Both the ways in which transportation projects are funded and the types of contracts used for their construction, maintenance and operation have important implications in terms of incentives and will considerably affect the correct estimation of the costs and benefits. Ignoring the importance of the type of concessionaire contract or the financing system of the project can lead to estimation errors and affect the outcome of the cost-benefit analysis. It is, therefore, essential to examine in depth the incentive problem inherent to the institutional design in which transport projects are framed, trying to quantify the consequences of the use of a particular form of funding (first stage) or concessionaire contract (second stage).

Most of the economic literature focuses on the analysis of the second stage, i.e. the relationship between the regional government and the concessionaire, discussing what type of contract provides the best incentives for the latter to be efficient. Most of these works consider that regional governments are managed by benevolent politicians who pursue the maximization of social welfare, ignoring the consequences of the institutional design in the first stage. However, **de Rus and Socorro (2009)** showed that the institutional design that determines how to ascertain national funds to finance the project can significantly affect the incentives of politicians and thereby the main results in the second stage. Thus, the national funding mechanism will determine the incentives of the regional government for selecting an efficient contract for the construction, maintenance and operation of the infrastructure, i.e. a contract that seeks the minimum cost and the maximum benefits from a social point of view.

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[43] For the case of investments at the supranational level, see **Turró (1999)** and **de Rus and Socorro (2009)**.

This Appendix will first analyze the first stage, i.e. the consequences of the institutional design in relation to obtaining national funds to carry out a given transportation project. Secondly, we will then focus on the second stage, i.e. the consequences that the type of contract has on the incentives of the economic agents involved in the construction, maintenance and operation of a particular transport infrastructure.

IV.1. Institutional design and project funding

Large infrastructure projects involve large investments, which regional governments usually can only carry out through cofinancing by the national government. In order to receive state funding, regional governments must submit a project to the Central Administration, which will decide on the appropriateness of the project and the need to cofinance it.

In general, regional and local governments know better than the central government the specific characteristics of the project and are able to more appropriately predict the benefits and costs generated by a specific project in their region. Therefore, the Central Government when deciding whether to fund or not a particular project faces a problem of asymmetric information.

On the other hand, the objectives of regional governments can differ from those pursued by the Central Administration for multiple reasons. The simplest difference is that, under the assumption that both governments pursue social welfare, the territorial dimension when implementing this final objective is not the same. Thus, it might happen that an infrastructure produces negative external effects outside region A that the regional governments do not consider, but the central government must incorporate in the process of its investment evaluation. Other times, projects can produce apparent benefits that in the strictest sense are just transfers that do not increase the wealth of the nation as a whole. Thus, from the regional viewpoint we can consider social benefits that are not so from a global perspective. This is the case of many indirect effects involving the deviation of economic activity.

Moreover, the discrepancy between the objectives pursued by the national government and regional governments can come from who receives the benefits. The central government might be interested in a railway line that crosses region A and whose social benefits are distributed equally between region A and the surrounding regions. In this case, the benefit from the perspective of the government of region A is half that considered by the central government when it decides where to invest. Another possible discrepancy between the national and regional objectives is caused when the project's social benefits are identical for both administrations, but the costs assumed by the central government are not considered by the regional governments as their own. Therefore, the net profit of the investment project is greater from the local perspective because regional governments underestimate the costs from a national perspective.

In this context of asymmetric information and conflicting objectives, how projects are funded can mean regional governments have an optimistic bias when presenting projects competing for national funds. In fact, empirical evidence has suggested that when presenting an investment project in infrastructure, regional governments tend to underestimate the costs, the execution times and the risks the project involves, whereas the benefits of the project are overestimated.

For example, it is estimated that the underestimation of costs in the construction of transport infrastructure is 44.7% for railways, 33.8% for bridges and tunnels and 20.4% for roads. The overestimation in passenger demand is also present, being 51.4% for rail projects **(Flyvbjerg, 2008)**. This optimistic bias can be because of, on one hand, prediction errors and, on the other hand, opportunistic behavior. In this sense, **Flyvbjerg (2004)** argued that given the institutional design that exists in most countries there are few economic agents in society that have incentives to minimize this optimistic bias.

Given the problem of asymmetric information, central agencies cannot always detect or correct this optimistic bias and thereby could be funding projects that are not socially optimal. In the case of several regional governments competing for national funds, the situation is even worse because the system provides incentives for regional governments to increase the optimistic bias in a behavior that resembles the prisoner's dilemma: although each regional government knows that this system leads to the implementation of suboptimal projects at the national level, individually they are interested in applying for a funding that would otherwise be spent on other regional governments **(Flyvbjerg, 2004)**. This strategic behavior is general and ends up in a suboptimal solution for all in which state funding grows without limit, which is detrimental to the whole nation. This is an irrational situation from a collective (national) perspective but contemplated at the individual level, from the regional perspective is completely rational.

On the other hand, **de Rus and Socorro (2009)** showed that if there are no budget constraints regional governments can have incentives to behave opportunistically to obtain more funding. This type of opportunistic behavior is the opposite of optimistic bias, because governments that are not competing for funding have incentives to reduce the revenues and increase the costs of the project, affecting the selection of projects, the size of the infrastructure, the choice of technology and the type of contract used for construction, maintenance and operation. Thus, with a funding mechanism that pays for the difference between total project costs (including investment costs, maintenance and operation) and the project's revenues there is no incentive to be efficient or charge for the use of the new infrastructure. Instead, with a funding mechanism that only pays for the difference between investment costs and project revenues, regional governments have incentives to charge the optimal price, although it is also true that there are no incentives to be efficient. Finally, a funding mechanism of a fixed amount achieves maximum efficiency and socially optimal pricing.

One possible solution to these problems of asymmetric information discussed above would be that the State mandates an independent agency to develop a cost-benefit analysis of projects submitted for funding and this is then compared the cost-benefit analysis with the one presented by regional governments. Although this measure could be costly, it would allow the central government to know in advance the true social benefits of the project to fund.

Another possible solution to the problem of asymmetric information is the *ex post* evaluation of transportation projects, which identifies the differences in expected costs and revenues and makes the results public. In the case of several regional governments competing for national funds, the evaluation of transportation projects could reduce optimistic bias. However, if there is no budget constraint this *ex post* evaluation would not reduce the incentives for regional governments to behave opportunistically in order to obtain more funding.

For any of the previous two policies (the development of an independent cost-benefit analysis and/or *ex post* evaluation) to be effective in reducing the opportunistic behavior of regional governments, it should be accompanied by penalization. Such penalization would not necessarily be monetary; it could simply be bad reputation for future negotiations.

Another possible solution would be to determine, on the basis of national and international experience, certain parameters to adjust the estimated costs and benefits of projects. These parameters will improve the accuracy of the *ex ante* evaluations of transport projects and minimize the "optimistic bias". This is the idea behind the so-called reference class forecasting method based on **Kahneman and Tversky (1979a, 1979b)** and **Kahneman (1994)**. The application of this method for a given investment project requires:

1. The identification of a suitable reference group, taking into account what has happened in the past with similar projects. This reference group should be large enough to have statistical significance but small enough to be truly comparable with the evaluated project.
2. The establishment of a probability distribution for the reference group selected. This requires access to a reliable database for a high enough number of projects within the reference group to draw statistical conclusions.
3. A comparison of the project evaluated with the probability distribution of the reference group, so we can draw the most likely outcome of the project analyzed.

Therefore, with the *reference class forecasting* method there is no attempt to eliminate the uncertainty associated with the projects, but to place a particular project within a probability distribution corresponding to the results of other projects in the reference group **(Flyvbjerg, 2008)**. This will minimize the so-called optimistic bias.

A suboptimal but much simpler policy could be to make a lump sum transfer to regional governments for them to administer, so that with that money and that of their budgets they would have to assume the full cost of the project or projects they decide to undertake. Funds received might be limited to be used only to achieve a specific national goal such as, for example, "improving accessibility", "improved safety", etc. Thus, each regional government would allocate public funds to achieve that goal with a project of given technical features and technology as it deems appropriate, without a bias towards a specific technology or projects of certain characteristics. In this way, we would leave the prisoner's dilemma mentioned above, in which all regional governments propose projects (though not socially optimal) because that is what the rest of regional governments do.

A lump sum transfer to regional governments seems the easiest and most efficient policy option to implement, with the additional virtue of being politically attractive by the delegation of responsibility that it implies. This policy is not incompatible with the requirement to submit a cost-benefit analysis to the central government by the regional governments, where they explain the purpose of the project, why it is justified that the project is the best way to achieve the objective and the flows of benefits and costs are identified and quantified. This complementary measure, without being costly, could be useful for regional governments themselves in selecting their own projects, and it would contribute to improve the practice of the economic evaluation of projects in Spain.

The first advantage of the lump sum financing system is the elimination of the strategic behavior of regional governments when obtaining state funding. Regional governments are now only interested in funding the best projects within their locality, because the funds are predetermined and they aim to get the most out of them. The second advantage is that, if the central government fixes *ex ante* the quantities, let us say for periods of five years, regional governments could plan their investments in transport in advance rather than respond to political negotiations full of strategic behavior. The third advantage is that it minimizes opportunistic behavior both if there is a budget constraint (optimistic bias and prisoner's dilemma) and if there is no budget constraint (opportunistic behavior for more funding). Given that national funds are predetermined there is no incentive to mask the project to obtain more state funding. Therefore, the problems of the loss of incentives to operate efficiently, inadequate project selection and strategic behavior in its relationship with the State are minimized with the lump sum system.

Finally, another measure that would alleviate the problem of asymmetric information faced by the national government when cofinancing transportation projects would be to increase, to the furthest extent possible, the degree of cofinancing by regional governments and/or private participation. **De Rus and Socorro (2009)** showed that the lower the percentage of state government funding, and therefore the higher the percentage financed by the regional government and/or the private sector, the greater the incentive to be efficient and price optimally. Also, **Flyvbjerg (2004)** argued that the rule of financing up to 25% of the total cost in some transport projects in the United Kingdom contributed to significantly reduce optimistic bias.

Whatever the measure finally adopted, any of the above proposals would alleviate the problem of asymmetric information faced by the national government in financing transportation projects, and would allow the cost-benefit analysis to be a useful tool for regional governments rather than a mere bureaucratic requirement to obtain state funding. Furthermore, none of these measures is exclusive, so they could be optimally combined.

Finally, note that before carrying out any public investment all possible alternatives should be considered, so that the ultimate objective would not be biased in the selection of a given technology. In this sense, it is desirable that regional governments propose several alternatives to the State in order to achieve a certain objective, and the selection of the best alternative is made based on efficiency criteria.

IV.2. Concession contracts

In general, companies that carry out a project for the construction, maintenance and/or operation of a transport infrastructure have more information than the regional governments about its costs and market conditions. Therefore, the regional governments, when deciding how to remunerate the concessionaire, face a problem of asymmetric information.

In a context of asymmetric information it is crucial that the contracts provide the necessary incentives so that agents do not behave opportunistically. Thus, the type of contract can affect the incentives of agents to be efficient and/or generate revenues (such as attracting new users to the infrastructure). Likewise, this can also bias the correct choice of technology with which the companies will build the new transportation infrastructure.

There are multiple ways in which governments can compensate the concessionaire for the construction, maintenance and/or operation of a transportation project, but basically they can be summarized in two: cost reimbursement contracts and lump sum contracts.

Cost reimbursement contracts are those for which the builder and/or concessionaire firm receives public funding only if it has losses. In case of losses, these are funded either entirely or as a percentage. This type of contract does not offer any incentives for companies to be efficient and/or attract users to the transport system because this is costly and funding is obtained only if the company has losses (see, for example, **Olsen and Osmundsen, 2005**).

A lump sum contract consists of making a fixed transfer to the company, regardless of its benefits. Thus, if firms are efficient enough they could keep the surplus. If not, they would have losses. This type of contract is optimal from the point of view of the incentives to build efficiently, to choose the most appropriate technology and to attract users. Thus, there is empirical evidence in other countries that operating costs are lower in companies that have lump sum contracts (see, for the French case, **Gagnepain and Ivaldi, 2002**, and for the Norwegian case, **Dalen and Gomez-Lobo, 1997, 2003**, or **Jorgensen *et al*., 1997**). Moreover, it is easy to predict the amount of money that the regulator should need to fund transport, minimizing the costs of obtaining public funds and equity issues. However, lump sum contracts generally involve a greater risk to the concessionaire, so they can increase the likelihood of renegotiation (**Guasch, 2004**). In this sense, it is necessary to have an optimal risk sharing scheme between the government and the concessionaire.

One possible solution would be to adjust *ex post* the fixed amount taking into account the relationship between incentives and risk sharing. Thus, the regulator should use the observed deficits and other variables, such as the price of production factors, as a source of information on the performance of the company. Small deficits are a major sign of a high effort if the prices of productive factors have been higher than if they have been lower. Therefore, for statistical inference, the fixed amount given to a company with small deficits must be greater if the prices of the factors have been higher than if they have been lower.

The subsidies per traveler give the company a fixed amount per passenger that uses the new infrastructure. If the concession period is variable, i.e. the concession lasts until it recovers the entire investment, subsidies per passenger entail the same results in terms of incentives as cost reimbursement contracts. Conversely, if the concession period is fixed, the concessionaire has strong incentives to reduce investment costs and attract users to the new infrastructure, so that the result in terms of incentives is like a lump sum contract.

In practice, there are infrastructure projects such as roads, where the basic problem with the introduction of a lump sum contract is the uncertainty of demand. The life of the project can last more than 40 years and the usual fixed term concession, a kind of lump sum contract widely used in the world, has several times become a cost reimbursement contract through renegotiation (**Guasch, 2004; Nombela and de Rus, 2004**). One solution to this problem is a new concession mechanism based on flexible term contracts and auctions (**Engel *et al*., 2001; Nombela and de Rus, 2004**). This new mechanism improves the outcomes compared with the fixed term system by eliminating the risk of demand and selecting efficient concessionaires.

IV.3. References

Dalen, D. M. and A. Gomez-Lobo (1997): “Estimating cost functions in regulated industries characterized by asymmetric information”, *European Economic Review*, 41, 935-942.

Dalen, D. M. and A. Gómez-Lobo (2003): “Yardsticks on the road: regulatory contracts and cost efficiency in the Norwegian bus industry”, *Transportation*, 30(4), 371-386.

de Rus, G. and M. P. Socorro (2009): “Infrastructure investment and incentives with supranational funding”. Department of Economics, Business, and Statistics, DEAS, University of Milan. Working Paper no. 2009-18.

Engel, E., R. Fischer, and A. Galetovic (2001): “Least-present-value-of-revenue auctions and highway franchising”, *Journal of Political Economy*, 109, 993-1020.

Flyvbjerg, B. (2004): “Procedures for dealing with optimism bias in transport planning”, Guidance Document. The British Department for Transport.

Flyvbjerg, B. (2008): “Curbing Optimism Bias and Strategic Misrepresentation in Planning: Reference Class Forecasting in Practice”, *European Planning Studies*, 16(1), 3-21.

Gagnepain, P. and M. Ivaldi (2002): “Incentive regulatory policies: the case of public transit systems in France”, *RAND Journal of Economics*, 33(4), 605-629.

Guasch, J. L. (2004): *Granting and renegotiating infrastructure concessions: Doing it right*, WBI Development Studies. The World Bank, Washington, D.C, United States.

Jorgensen, F., P. A. Pedersen and R. Volden (1997): “Estimating the inefficiency in the Norwegian bus industry from stochastic cost frontier models”, *Transportation*, 24(4), 421-433.

Kahneman, D. (1994): “New challenges to the rationality assumption”, *Journal of Institutional and Theoretical Economics*, 150, 18-36.

Kahneman, D. and A. Tversky (1979a): “Prospect theory: An analysis of decisions under risk”, *Econometrica*, 47, 263-291.

Kahneman, D. and A. Tversky (1979b): “Intuitive prediction: Biases and corrective procedures”, en S. Makridakis and S. C. Wheelwright (Eds.), *Studies in the Management Sciencies*: *Forecasting*, 12, 313-327. Amsterdam, North Holland.

Nombela, G. and G. de Rus (2004): “Flexible-Term Contracts for Road Franchising”, *Transportation Research A*, 38 (3), 163-247.

Olsen, T. and P. Osmundsen (2005): “Sharing of endogenous risk in construction”, *Journal of Economic Behavior & Organization*, 58(4), 511-526.

Turró, M. (1999): *Going Trans-European: Planning and Financing Transport Networks for Europe*, Ed. Pergamon.