Intergenerational redistributive effects due to the financing formula of investments in transport infrastructure. A microeconomic analysis

Domingo Peñalver Rojo

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Departament d'Infraestructura del Transport
i del Territori

PhD Thesis

-Tesi per compendi de publicacions-

INTERGENERATIONAL REDISTRIBUTIVE EFFECTS DUE TO THE FINANCING FORMULA OF INVESTMENTS IN TRANSPORT INFRASTRUCTURE. A MICROECONOMIC ANALYSIS

Author:

Domingo Peñalver Rojo

PhD Supervisor:

Dr. Mateu Turró Calvet

Programa de Doctorat en Enginyeria i Infraestructura del Transport

Universitat Politècnica de Catalunya – BarcelonaTech

Barcelona, March 2019

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Departament d'Infraestructura del Transport i del Territori

INTERGENERATIONAL REDISTRIBUTIVE EFFECTS DUE TO THE FINANCING FORMULA OF INVESTMENTS IN TRANSPORT INFRASTRUCTURE. A MICROECONOMIC ANALYSIS

Autor:

Domingo Peñalver Rojo

Director de la tesi:

Dr. Mateu Turró Calvet

Memoria presentada per optar

al titol de Doctor Enginyer de Camins, Canals i Ports

Programa de Doctorat en Enginyeria i Infraestructura del Transport

Departament d'Enginyeria Civil i Ambiental

E.T.S. d'Enginyers de Camins, Canals i Ports de Barcelona (ETSECCPB)

Universitat Politècnica de Catalunya – BarcelonaTech

Barcelona, March 2019

To my family, wife, son and daughter.

They have been next to me all the time

(...) same experiences make of the sequence of life cycles a generational cycle, irrevocably binding each generation to those that gave it life and to those for whose life it is responsible. Thus, reconciling lifelong generativity[(*)] and stagnation involves the elder in a review of his or her own years of active responsibility for nurturing the next generations, and also in an integration of earlier-life experiences of caring and of self-concern in relation to previous generations.

Erikson, Erik. H., Joan M. Erikson and Helen Q. Kivnick . Vital involvement in the old age. WW Norton & Company, 1994.

[(*)] The concept of *generativity* refers to the individuals' interest to guide and ensure the well-being of next generations and, ultimately, to leave a legacy that will survive us.

INTERGENERATIONAL REDISTRIBUTIVE EFFECTS DUE TO THE FINANCING FORMULA OF INVESTMENTS IN TRANSPORT INFRASTRUCTURE. A MICROECONOMIC ANALYSIS

Domingo Peñalver Rojo

Abstract

Investments in major transport infrastructure projects involve a significant mobilisation of economic resources both for construction and operation. In these projects, to assess the efficiency of the resources used, decision-makers usually use cost-benefit analysis (CBA). This key element of welfare economics is carried out taking into account the effects for society as a whole. Social welfare is thus measured independently of who are the components of society receiving the benefits or suffering the costs. However, besides the best use of resources, which should be always ensured, transport projects often have other objectives. These objectives, which are ideally defined by the political programs of elected decision-makers, often involve redistributive effects. Favouring the economic development of less advanced regions is, for instance, an argument that is used to justify territorial biases in investment.

Practitioners have increasingly tried to identify redistributive effects to both create awareness of their existence and to quantify them in order to incorporate them rigorously in project appraisal. Intergenerational redistributive effects due to the financial scheme adopted for the project are a kind of redistributive effects that has neither been properly highlighted nor researched until now. The actual payments to cover the costs of projects unfolding over long timespans depend on the financing formula chosen and affect taxpayers and/or users of different generations. When transport investments are directly covered by the annual budgets of public administrations, they are paid by the taxpayers of the construction period but benefit users that will live in decades ahead. However, if the project is financed through loans, their payment schedule will define a very different financial time-profile. Relating the payments profile with the benefits produced by the project, which occur over its life cycle, can indicate the fairness of the distribution of expenditure and benefits across the successive generations affected by the project.

At microeconomic level, intergenerational impacts have been discussed, often with insufficient rigor, in relation to environmental sustainability and mostly regarding the appropriate discount rate to be applied in CBA. However, the financial structuring of the project could have a much stronger impact on a project's legacy. The issue of the long-term implications of financial decisions is illustrated, at a broader macroeconomic level, by the problems of public debt confronted by many countries.

In this work the redistributive effects of transport investment projects are analysed, though the major contribution is the development of the *"Intergenerational Redistributive Effects Model"* (IREM). This microeconomic model allows performing an analysis of intergenerational impact for both major project of transport infrastructure and integrated investment programmes that is useful to obtain indicators of their utility for the successive (overlapped) generations concerned. Decision makers and financiers may use the IREM's outputs when proposing a financial montage for a project and deciding the participation of private stakeholders and the contribution of users in it. They also can use the IREM's indicators as insights to establish the most convenient financial montage to carry out a project.

In synthesis, what is presented, developed and tested is a tool to characterise the intergenerational impacts from major transport investment. These effects should be included in the wide concept of project sustainability but have, until now, been disregarded in spite of their importance for decision makers and financiers.

Keywords: intergenerational redistributive effects; intergenerational impact analysis; IREM; CBA; white elephant; public-private partnerships; project finance; value for money

Mateu Turró, PhD

Professor (Catedràtic) of Transport and Regional Planning

School of Civil Engineering − Universitat Politècnica de Catalunya (UPC) − Barcelona Tech

March 2019

Acknowledgements

I want to thank prof. Dr. Mateu Turró for his time and patience as both PhD supervisor and teacher. His masterful teaching concerning transport economics in general and, in particular, cost-benefit analysis and project financing still inspires me. Thanks for being there all the time. Indeed, this doctoral thesis is a result of our joint effort and mutual collaboration.

My family also deserves a special mention here, since they have experienced “the good, the bad and the ugly” of making a PhD. A huge dosis of understanding, support, patience and love, especially from my wife, has been necessary to get both the energy and the determination required to arrive to the end of this trip.

My gratitude is also for Dra. Diana Zavala-Rojas, researcher at the Faculty of Political and Social Sciencies of the Universitat Pompeu Fabra, and for Dr. John B. Williamson, professor at the Deparment of Sociology of the Boston College. Their work has been critical to both produce and publish the scientific papers of this doctoral thesis.

I want also to thank prof. Dr. Bent Flyvbjerg and, especially, prof. Dr. Alexander Budzier for their support during (and afterwards) my academic stage at The Saïd Business School of the University of Oxford. I want also to show my acknowledgment to both the European Investment Bank (EIB) and the EIB Institute staff, in particular Dr. Doramas Jorge, who channelled my fellowship, and to Dr. Sergi Saurí and my colleagues in the Center for Innovation in Transport (CENIT).

A part of this research was financially supported by the EIB through the STAREBEI Programme and the CENIT. The findings, interpretations and conclusions presented in this document, and any possible error, fall entirely under the responsibility of the authors and should not be attributed in any manner to the European Investment Bank or CENIT.

Finally, I want to thank both Dr. Massimo Florio, professor of Public Economics at the Department of Economics, Management and Quantitative Methods of the University of Milan, and Dra. Georgina Santos, professor at the School of Planning and Geography of the University of Cardiff, for their work as independent (external) reviewers of this doctoral thesis.

March 2019

Table of contents

List of figures

List of tables

List of equations

SECTION I. INTRODUCTION, OBJECTIVES AND CONTRIBUTIONS

1. BACKGROUND AND OBJECTIVES

Major transport infrastructure projects mobilise a great amount of economic resources during very large timespans that may extend well beyond a service live of 50-75 years. As a consequence, they generate significant social, territorial and environmental effects that concern multiple generations. The socioeconomic evaluation of these projects through cost-benefit analysis (CBA) is a widespread and consolidated practice in many countries and is used by major *International Financial Institutions (IFIs)* to appraise projects presented to them for financial support (Turró, 2010). There is a proliferation of guides and manuals on how to carry out CBAs for major investments (WB, 1997; ADB, 1997; ABTE, 1999; BID, 2006; Turró, 2004; DG Regio-EU, 2015). They are not always consistent, but they systematically apply the basic principles of CBA, among them that present benefits (i.e. resource consumption) are considered more valuable than future one (Pigou, 1920; Ramsey, 1928; Harrod, 1948). Indeed, to compare the costs and benefits for society occurring throughout the project's economic life cycle, they must be properly quantified and monetised and then discounted using precisely the rate that supposedly reflects the value loss for society of consuming later. The results of the CBA are presented by means of synthetic indicators, such as the net present value (NPV), showing the total of the discounted net benefits, the internal rate of return of the investment or the ratio between the discounted benefits and costs.

The outcomes from the standard socioeconomic CBA give therefore an indication of the capacity of the project to generate net benefits, in terms of resources, for the society of the time when the decision must be taken. A substantial problem in the use of CBA indicators as a main decision-making tool is that, in some cases, there are important effects that cannot be properly quantified and/or monetised or are controversial. Environmental impacts, for instance, are given economic values that are increasingly precise (Cavill et al., 2008; Vandermeulen et al., 2011), but some of them, such as those for greenhouse gases emissions, are far from obtaining consensual monetisation. Certain impacts, such as landscape effects, are particularly hard to convert into money. Other effects of infrastructure projects, such as the incidence on economic development, are also difficult to incorporate in the CBA. Some mechanisms to do it, such as using shadow values for labour, to enhance the job creation potential of the project, are sometimes applied, but the incorporation of the potential effects of a transport infrastructure on the economy is far from being a standard practice. The really relevant effects of a project that are difficult to include in the CBA may be taken into consideration through a multicriteria analysis or simply by comparing the project's NPV with these effects to see if they are, at least, within the order of magnitude that would ensure a positive NPV[1].

The CBA does not provide, however, information about the effects of the project on the various social groups, or stakeholders, that will benefit from, or in some cases, be harmed by, the investment. If a project has to fulfil the Pareto-efficiency condition, besides being socioeconomically profitable, all individuals should obtain benefits, even those that are a priori adversely affected, which must necessarily be compensated (de Rus, 2009). However, in practice, this condition is rarely complied with. Most transport projects effects are not distributed homogeneously across the territory, the various social groups or over time. The unequal distribution of costs often means that the negative impacts for certain stakeholders are left without a proper compensation. Whilst such effects do not affect the overall efficiency of the project measured by the CBA, it is obvious that Paretian efficiency is not ensured. Onwards,

[1] If the effects are negative, they should be inferior to the positive NPV of the project and, alternatively, when positive, they should be considered at least sufficient to raise a negative NPV to zero.

those differential impacts resulting from an unequal distribution of the socioeconomic benefits and costs of the project are referred to as “redistribution effects”.

The environmental redistribution effects generated by infrastructure construction and by transport services, which affect different geographic areas and social groups, have been widely analysed. The development of specific procedures that allow their identification and mitigation, such as the strategic environmental assessment (SEA) or the environmental impact assessment (EIA) − (Lee & Wood, 1978; Jörissen & Coenen, 1992; Arce & Gullón, 2000; Glasson et al., 2013)− is a good proof of this. Furthermore, at present, environmental sustainability is a clear political objective of the European Union (EU) and of most countries, including many less developed ones. When investment projects aim at obtaining financial support (funding) from the EU or financing from IFIs or other international institutions promoting social and economic development, the analysis of their environmental aspects is always a main requirement (Turró, 2010).

Territorial spillover effects, induced by changes in regional accessibility, are linked to the multiple equilibria affecting the conditions of economic growth and are difficult to foresee and quantify. Their long-term implications are obvious and, alongside some environmental impacts, they should be incorporated into any concept of intergenerational redistributive effects. The effects over future generations stemming from the project’s financing formula, which usually involves delayed payments, have not been properly identified until now in spite of being evident. **The main objective of this thesis is to explore the redistribution effects of the mechanism adopted to finance major transport infrastructure projects and to propose ways of incorporating these effects in the decision-making process.**

2. MAIN CONTRIBUTIONS OF THE THESIS

This thesis is the result of a compendium of papers published in SCI’s peer-reviewed journals of international scope. The major contributions of those scientific articles to the literature are:

1) Classification, for first time, of the redistribution effects arising from major investments in transport infrastructure. Redistribution effects, which should be considered alongside the socioeconomic and financial assessment, are seldom reflected in a systematic way in the decisions on major infrastructure investments. The proposed classification should facilitate a more consistent incorporation of these effects in the decision-making process.

2) Development of the *Intergenerational Redistributive Effects Model* (IREM) architecture. This microeconomic model provides a set of indicators allowing to perform an analysis of the intergenerational impact of major projects of transport infrastructure.

3) As IREM is based on a survey-based definition of the *generation* concept, it has been necessary to design an ad-hoc utility function that represents the dynamic of society’s preferences within each generation in relation to the main features and effects of major infrastructure projects. This function provides a mathematical representation of the generational concept, which has been key to the practical application of IREM to a set of transport-infrastructure projects already commissioned.

4) Development of a *projects intergenerational rating scale* that allows to label a project in terms of *fairness/unfairness*[2]. This scale may be to evaluate: a) if certain generations are paying (or expected to pay) more than the net benefits they receive; b) whether present or future generations will be favoured and the strength of this trend; and c) whether particular generations will end up being greatly benefited/harmed due to the project financing model.

5) IREM has been applied to a set of projects of different typologies. The results indicate that this microeconomic tool is suited to perform a proper analysis of intergenerational redistributive effects. The IREM indicators offer valuable insights to identify those projects that would represent a clearly unfair treatment of future generations, in spite of showing an acceptable socioeconomic return for the current society.

6) The outcomes obtained during this research provide strong arguments in favour of:

   ~ including the assessment of the fairness of the redistribution of the project effects across the generations concerned in the decision-making process to major projects of transport infrastructure with the aim of identifying those projects that would represent a clearly unfair treatment of future generations, in spite of showing an acceptable socioeconomic return for the current society.

   ~ including in the *Value for Money* analysis of public-private partnerships (PPPs), besides the standard efficiency and financial considerations, an analysis of the intergenerational effects of the different procurement options and to compare these effects with those of the purely public financing alternative

Indeed, a major finding of this research is that the negative impact from an unbalanced distribution of the project's socioeconomic net benefits in relation to the financial provisions has the potential to reduce the well-being of future generations, being users and/or taxpayers. Although the long-term effects of the financing formula of a specific project are evidently embedded in the global macroeconomic context, (i.e. public deficit and debt), the results of the thesis indicate that it is important, within the decision-making process, to generate awareness of its intergenerational implications. The selection of the most suitable option to finance a major infrastructure project should include the consideration of the fairness of the distribution of costs and benefits among different generations.

3. PUBLICATIONS FROM THIS THESIS

The present doctoral thesis is the result of a compendium of scientific papers published in indexed international journals falling in the framework either transport economics or project management and decision-making processes:

A. Papers published in international SCI journals:

   - Penyalver, D. & Turró, M. (2017). Assessing the fairness of a project financing formula on successive generations. International Journal of Transport Economics, 44(1), pp.153-176. https://doi.org/10.19272/201706701008

[2] The "fair/unfair" concept refers to moral obligations towards future generations (Rawls, 1972).

- Penyalver, D., Turró, M. & Zavala-Rojas, D. (2018). Intergenerational perception of the utility of major transport investments. Research in Transportation Economics, 70, pp.97-111. https://doi.org/10.1016/j.retrec.2017.11.001

- Penyalver, D. & Turró, M. (2018). A classification for the redistributive effects of investments in transport infrastructure. International Journal of Transport Economics, 45(4), pp.689-726. https://doi.org/10.19272/201806704008

- Penyalver, D., Turró, M. & Williamson, J.B (2019). Measuring the value for money of transport infrastructure procurement; an intergenerational approach. Transportation Research Part A: Policy and Practice, 119, pp.238-254. https://doi.org/10.1016/j.tra.2018.11.013

- Turró, M. & Penyalver, D. (2019). Hunting white elephants on the road. A practical procedure to detect harmful projects of transport infrastructure. Research in Transportation Economics (in press). https://doi.org/10.1016/j.retrec.2019.03.001

4. OUTLINE OF THE THESIS

Once the main background of decision-making processes for major investment in transport infrastructure has been introduced and the objectives and contributions of the thesis are described, the remainder of this thesis is structured according to Figure I-1.

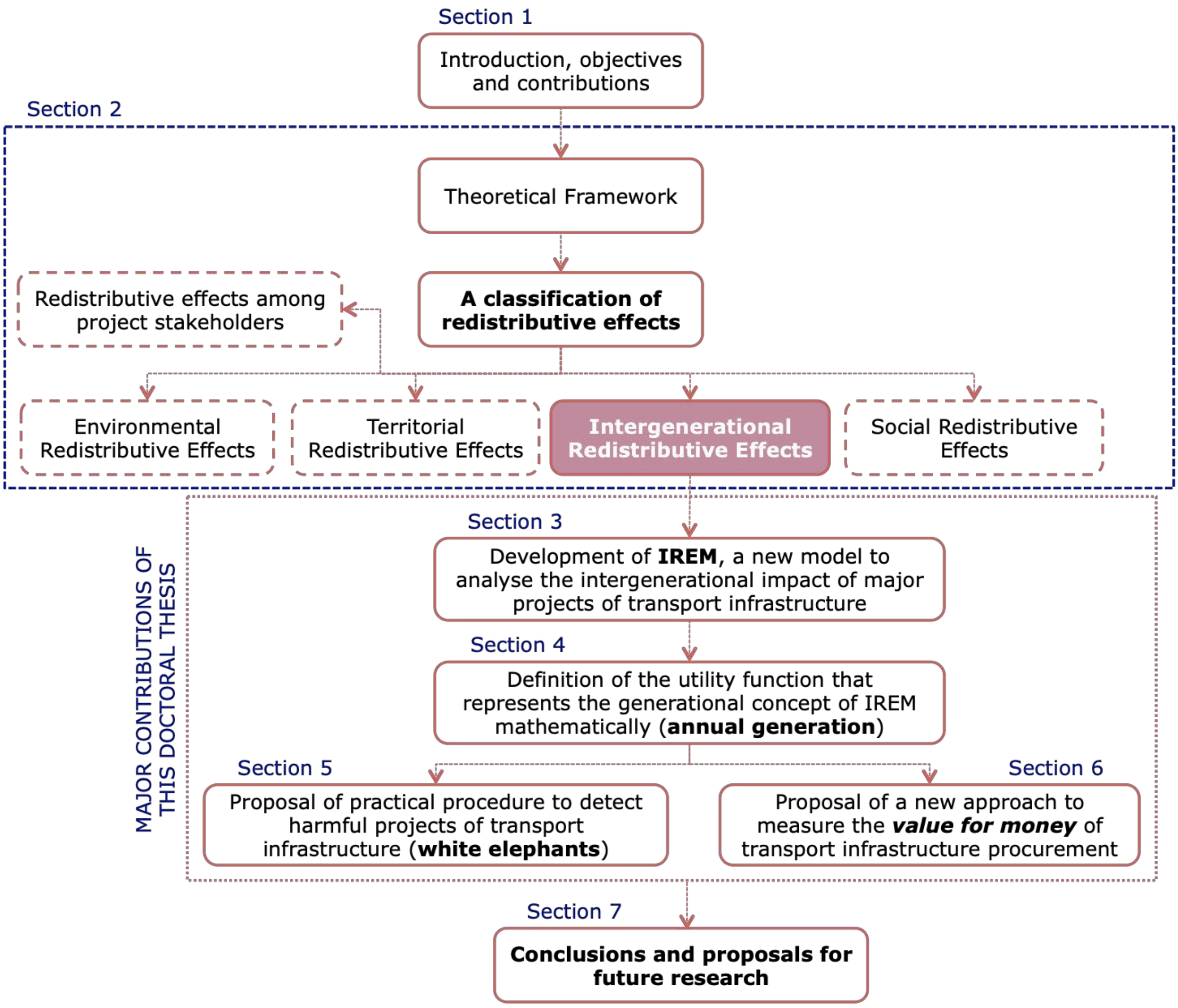
In particular, **Section II** addresses the theoretical economic-framework and the main decision-making instruments used by governments promoting investments in transport infrastructure and provides a classification of the redistributive effects of major investments projects in transport infrastructure. This section matches with the paper entitled: *"A Classification for the Redistributive Effects of Investments in Transport Infrastructure"*.

Section III develops in detail the IREM model, which is a comprehensive microeconomic approach that allows establishing the importance of the intergenerational redistributive effects. This section matches with the paper entitled: *"Assessing the Fairness of a Project Financing Formula on Successive Generations"*.

Section IV describes the field work (surveys) and the methodological process followed to gather the insights required to establish, with a degree of suitable objectivity, the importance that individuals give to both the socioeconomic benefits obtained from transport infrastructure projects and the financial burden that they end up enduring. The results obtained from this work are indispensable to define the concept of *"annual generation"*, a core element within IREM. This section matches with the content of the paper entitled: *"An Assessment of the Catalonia Population's Time Perception about the Utility of Major Transport Investments"*.

Section V proposes a procedure for rating projects from the intergenerational perspective that is useful to avoid harmful transport-infrastructure projects (white elephants). To show the usefulness of such approach, IREM is applied to a set of motorway projects carried out in Andalusia (Spain). This section matches with the content of the paper entitled: *"Hunting White Elephants on the Road. A Practical Procedure to Detect Wasteful Projects of Transport Infrastructure"*.

Figure I-1. General overview of the thesis contents



Section VI highlights the importance of looking closely at the intergenerational effects of the adopted financing mechanism to ensure its fairness and convenience. This section matches with the content of the paper entitled: *"Measuring the Value for Money of Transport Infrastructure Procurement; An Intergenerational Approach"*.

Section VII offers an interpretation of the main findings from this research and delivers conclusions. Finally, a set of new lines of research are suggested to be developed in the future.

5. REFERENCES

- ABTE, 1999. *Facts and Furphies in Benefit-Cost Analysis*. Bureau of Transport Economics of Australia.
- ADB, 1997. *Guidelines for Economic Analysis of Projects*. Asian Development Bank.
- Arce, R. & Gullón, N., 2000. The application of strategic environmental assessment to sustainability assessment of infrastructure development. *Environmental Impact Assessment Review*, 20(3), pp.393-402.
- BID, 2006. *Evaluación económica de proyectos de transporte*. Banco Interamericano de Desarrollo.
- Cavill, N. et al., 2008. Economic analyses of transport infrastructure and policies including health effects related to cycling and walking: A systematic review. *Transport Policy*, 15(5), pp.291-304.
- de Rus, G., 2009. La medición de la rentabilidad social de las infraestructuras de transporte. *Investigaciones Regionales (Sección Panorama y Debates)*, 14, pp.187-210.
- DG Regio-EU, 2015. *Guide to cost-benefit analysis of investment projects. Economic appraisal tool for Cohesion Policy 2014-2020*. Directorate General Regional Policy of the European Commission.
- Glasson, J., Therivel, R. & Chadwick, A., 2013. *Introduction to environmental impact assessment*. Routledge.
- Harrod, R.F., 1948. *Towards a dynamic economics*. London: Macmillan & Co.
- Jörissen, J. & Coenen, R., 1992. The EEC Directive on EIA and its implementation in the EC member Estates. In *Environment Impact Assessment Eurocurses*., 1992.
- Lee, N. & Wood, C., 1978. Environmental Impact Analysis. A European Prespective. *Built Environment*, 4(2), pp.101-10.
- Pigou, A.C., 1920. *Economics of welfare*. London: Macmillan.
- Ramsey, F.P., 1928. A mathematical theory of saving. *Economic Journal*, 38(152), pp.543-59.
- Turró, M., 2004. *RAILPAG. Railway Project Appraisal Guidelines*. ed. European Commission and European Investment Bank. (http://www.eib.org/projects/publications/ railpag-railway-project-appraisal-guidelines.htm).
- Turró, M., 2010. La evaluación de proyectos de inversión en transporte por parte de las instituciones financieras internacionales: la experiencia del Banco Europeo de Inversiones. *Cuadernos Económicos de ICE*, (80), pp.49-65.
- Vandermeulen, V. et al., 2011. The use of economic valuation to create public support for green infrastructure investments in urban areas. *Landscape and Urban Planning*, 103(2), pp.198-206.
- WB, 1997. *Handbook on Economic Analysis of Investment Operations*. World Bank.

SECTION II. A CLASSIFICATION FOR THE REDISTRIBUTIVE EFFECTS OF INVESTMENTS IN TRANSPORT INFRASTRUCTURE

Penyalver, D. & Turró, M., 2018

Abstract

The efficiency of major transport projects in terms of resources ought to be always a critical factor in decision-making. The socio-economic profitability of transport investment projects is unevenly distributed among their stakeholders, usually following pre-defined political objectives. This paper classifies the differential impacts of such projects (redistributive effects), including territorial, social and environmental impacts, to facilitate decision-making and proposes to include in this process the intergenerational seldom taken into account in the economic and financial assessment of major infrastructure investments. The classification proposed will facilitate giving to each redistributive effect a proper weight in a systematic multi-criteria analysis.

1. INTRODUCTION

Traditionally, the branch of Economics dealing with economic efficiency and social welfare considers society as an abstract and compact body (Bonnafous & Masson, 2003). In the classic formulation of welfare economics, public actions (plans, programs and projects) are evaluated, in principle, regardless of which individuals are taking advantage of them and which ones are suffering their consequences (Harberger, 1971). From a collective point of view, an investment will always be justified if the project allows a future consumption large enough to compensate for the postponement of immediate consumption of the resources required to carry out the project. Major infrastructures, due to their impact on society, are always either proposed or regulated by the public sector, which is typically an administration or a public agency, that is referred here as the *government promoting the investment* (GPI). The GPI is expected to ensure that society's resources are used efficiently and is ultimately responsible to determine whether to make the investment and under what conditions.

Efficiency for the whole of society is, thus, in theory, the driver of GPI's decisions. Such efficiency is traditionally measured using cost-benefit analysis (CBA[1]) (Thomopoulos et al., 2009; Meunier et al., 2013), which, based on the estimation of the costs and benefits of an action, such as an investment, over the time period that is considered relevant, monetises them and, using a social discount rate (SDR), produces quantitative indicators of its profitability. In principle, an investment will always be justified if the economic net present value (ENPV) of the project is positive or the internal rate of return (IRR) is higher than the SDR (Weisbrod, 2015; Boardman et al., 2017).

There are many issues in CBA, such as forecasts, monetisation and even about the right SDR that will not be raised here unless required. The focus of this article is on a major hindrance of CBA for proper decision-making, which is its difficulty to measure the differential impact of the project on the various stakeholders participating in it. In general, when a large transport investment is undertaken, some groups (in principle, the users of the project) will benefit noticeably from its effects while others (e.g. those affected by externalities and the taxpayers, when there are public subsidies) bear costs without being fairly compensated for them (de Rus, 2009). In order to ensure Pareto efficiency, so none of these agents is adversely affected or, if so, is properly compensated by the beneficiaries, it is important to identify the redistributive effects associated with the project. In a democratic environment in which both social fairness and the reduction of wealth inequality are usually pursued, it is difficult to justify that public decisions be only guided by the overall-efficiency principle (Khraibani et al., 2016).

Considerations related to efficiency on the one hand, and those from fairness, welfare and social and political peace on the other, are relevant for the decision-making process (Galindo, 1963). Traditionally, transport infrastructure investment addresses equity[2] issues, although not always

[1] CBA is the main instrument used by decision makers in the appraisal of transport investment projects, though the analytical framework varies somewhat from one country to another as there is no universal agreement on the extent to which costs and benefits should be disaggregated, which effects should be included in the analysis and how they should be monetised (OECD, 2002).

[2] Discussions about equity touch upon deep philosophical issues regarding fundamental values including society's moral obligations to others (Scanlon, 1998) and the question of which social improvement criteria should be preferred is unresolved (Feldman & Serrano, 2006). These discussions may be channelled through three fundamental theories: one based on a principle of "equal treatment", which holds that all individuals should get the same benefits of a service, another based on the "utilitarianism principle", which aims to maximise the overall welfare of society as a whole – this implies accepting that distribution of benefits among individuals is optimal and that they are indifferent to the way benefits are distributed (Bonnafous & Masson, 2003) –, and finally one based on the "Rawls criterion", which holds that society's "justice & fairness" is maximized when the project is selected to ensure that it is the best for the worst-off persons (Rawls, 1972; Rawls, 1974).

explicitly (Litman, 1996; Viegas, 2001; Raux et al., 2006). For example, investment initiatives seeking to fill a gap in mobility and accessibility between population groups typically pursue certain redistributive effects of social character (Blumenberg, 2002; Hine & Grieco, 2003; Karen, 2006; Martens, 2006; Hine, 2008). However, such objectives are rarely stated in the decision-making process and, therefore, seldom ranked alongside efficiency, possibly because they depend on complex interrelationships and, thus, are subject to uncertainty.

Equity analyses may be performed using different dimensions with the aim of providing evidence to the public in general concerning the fairness in the physical distribution of goods, accessibility for people, affordability of all types of services and distribution of other gains (Litman, 1996; Viegas, 2001; Raux et al., 2006; Beyazit, 2011; Trannoy, 2011). Horizontal[3] equity analyses may be useful to assess if there are transfers among different groups of individuals with similar characteristics. Vertical[4] equity analyses put the spotlight on how the effects of a project are distributed among groups of individuals of a different sort. Equity would imply that those in a worse situation (for example, individuals with lower per capita income or those who live in an area with poor accessibility) receive more public resources than those who are in a more privileged position.

How to integrate equity considerations (redistribution objectives) in the decision-making process in general and, in particular, in the efficiency analysis is still a major subject of discussion. Transport infrastructure projects are, nevertheless, possibly the most interesting to discuss in this endeavour as they can contribute both to overall growth and to the redistribution of the project benefits (OECD, 2002; ITF, 2018). Accessibility improvements generate reorganisation phenomena of the socioeconomic fabric with evident territorial and social implications. The environmental effects of the construction, maintenance and use of transport infrastructure are quite clearly distributed among local, regional and global scales. Finally, by the magnitude of the investments and their long lifecycle, it is relevant to assess the fairness of the distribution of their effects on the many generations affected.

The paper is organised as follows: Section 2 identifies and classifies the different redistributive effects that are more often generated by major transport infrastructure projects and how they are incorporated into the decision-making process. Section 3 provides arguments concerning the convenience of incorporating, in a transparent way, these effects in the decision-making process and some ideas on how to do it. Finally, Section 4 offers general conclusions and policy recommendations.

2. REDISTRIBUTION EFFECTS. REVIEW AND CLASSIFICATION

Major transport infrastructure investments entail a diversity of redistribution effects, both positive and negative, that may be relevant in the decision-making process. Until now, academics and practitioners have mostly focused on forecasting/ascertaining the effects of these projects on particular population groups, territories or generations. The wider redistribution issues stemming from the differential impacts of major investments have not been properly addressed. For example, in the field of real estate valuation, some researchers have provided evidence indicating that, overall, enhancing accessibility conditions through new transport infrastructure increases real estate values[5]. The expected increase is often incorporated in the

[3] Horizontal equity refers to the equal treatment of equals (Mooney & Jan, 1997).

[4] Vertical equity refers to the unequal, but equitable, treatment of unequals (Mooney & Jan, 1997).

[5] The outcomes of some studies, for instance in locations near new stations (Hess & Almeida, 2007; Mulley, 2014; Higgins & Kanaroglou, 2018), support this argument.

CBA as a benefit. However, it could be argued that, in a context of perfect competition and stable demand, such change would imply a (probably marginal) reduction in the real estate values in the rest of the city. This kind of redistributive effects in the territory have passed mostly unnoticed to local decision makers[6]. This situation, as will be seen, is common for all redistribution effects.

A systematic and thorough review[7] of the literature on transport project appraisal has led to the conclusion that a proper identification and classification of redistribution effects has never been attempted and could be a genuine contribution to the decision-making process on major projects.

The first level of redistribution effects that seems logical to analyse are those internal to the project. Costs and benefits included in the efficiency measures included in the CBA are normally taken as global figures representing the resources that are consumed (for instance, construction costs) or produced (for instance travel time savings). But these resources affect society through the agents directly involved in the project (the GPI, investors, constructors, operators, different users, etc.). A proper forecasting exercise, which is an essential component of the CBA, will identify the various stakeholders involved in the project and establish the expected effects on them, even though, as already said, they are eventually added up in the CBA. It seems thus reasonable to use this background information to better understand the economic and financial effects of the project, at least on its key stakeholders, to check if their distribution is reasonable.

A second level for the redistribution analysis is the identification and estimation of the differential effects that are usually not included in the CBA because they are difficult to monetise. These effects are generally more related to equity than to economic profitability. Indeed, many social, environmental, and spatial effects resulting from investments in transport infrastructure, which are increasingly mentioned in the decision-making process, are not even measured and seldom analysed with a certain rigour. They are, however, the aim of specific policies seeking to develop the poorest regions, help social groups with less resources, reduce environmental impacts, etc. On the other hand, the most credited redistribution effects, which may be classified into three broad categories: territorial, social and environmental[8] will only be observable in the long range[9].

At the European level, these policy-based effects are pursued by specific EU programmes and by institutions, such as the European Investment Bank, created to financially support them. Most EU subsidies are devoted to the economic development of eligible countries and regions[10] or to specific sectors, such as agriculture. Additionally, both EU environmental legislation and sector policies, particularly in transport and energy, have a clear bias in favour of "clean" solutions.

Finally, it is possible to identify a third level where the redistributive effects take an even broader perspective. These are the intergenerational redistributive effects, i.e. the differential impact that a project has on the generations being affected by the project during its life cycle. This third category gathers some aspects linked to the previous levels, such as the effects on

[6] Where decisions are made at state or regional level, local decision makers are very concerned with the potential redistribution of economic activity, but less concerned if these gains are made at the expense of other jurisdictions (ITF, 2017; Bermejo & Hoyos, 2016).

[7] For more details, see Appendix A enclosed.

[8] Other EU policies, for instance supporting research and innovation or better education, are left out of this first classification because they have less relevance for transport infrastructure.

[9] Some effects may be included in the CBA through induced traffic over time, for instance, but future users are not identified as separate beneficiaries in the CBA.

[10] Some countries are eligible to grants from the Cohesion Fund and "convergence" regions (mostly those with GDP per capita below 75% of EU average) to ERDF (European Regional Development Fund).

climate change, but it includes a specific redistributive effect due to the variability, across the different generations affected by the project, of the financing gap between what they will pay and the benefits they will obtain. This effect has not been addressed so far in the literature but deserves special attention.

2.1. REDISTRIBUTION EFFECTS AMONG PROJECT-LINKED STAKEHOLDERS

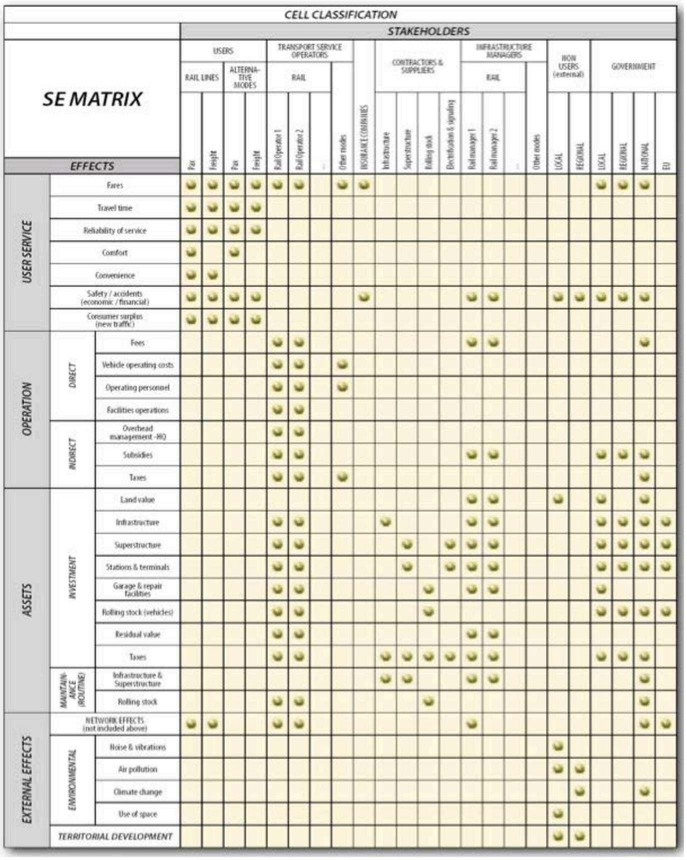
The process of preparation, construction and operation of a transport infrastructure entails economic and financial flows for a multitude of stakeholders directly involved in the project, including the various levels of government. However, conventional CBA merges effects (costs and benefits) according to standard typologies, without showing how project effects are distributed among concerned stakeholders (ITF, 2017). Both in terms of costs (preparation, construction, maintenance, operation, etc.) and benefits (for different types of users and other beneficiaries) or externalities (positive or negative) it is necessary to know how they are going to be produced and who is going to be affected throughout the life cycle of the project to quantify and monetise them.

The Stakeholders/Effects Matrix (Turró, 2004) represents a significant methodological advance in the identification of the transfers amongst the various agents participating in the project (cf. Figure II-1). The information needed to build the SE Matrix should be obtainable from the preparatory studies needed to carry out the CBA. Every significant relationship between a specific effect and a particular agent (in principle, those effects and agents appearing in the matrix[11] –cells with grey background in Figure II-1–) should be reflected in terms of net present values (NPV) of the specific effect on the agent in the corresponding cell. In each cell there should be the financial NPV (FNPV), when the effect has a market value adequately reflecting the socioeconomic value[12] (i.e. used in the CBA), or this financial value accompanied by the NPV of the difference of this value and the socioeconomic value adopted in the CBA). When this is not the case, the matrix should have a split cell with, on one section, the financial value and, on the other, the NPV of the difference between this amount and the socioeconomic value adopted in the CBA. For example, if a shadow value for labour is adopted, the real amount to be paid to workers, i.e. the real financial flow, will be seen in one section of the cell alongside, in the other section, the amount (usually a percentage of the real payments) that represents the social benefit of additional job creation (presented as a cost reduction in the CBA). It must be stressed that the total financial flows among the different agents should be nil as they represent pure cash transfers (fares, tolls, taxes and payments to builders, operators, etc.). The sums of the values in the columns of the SE Matrix indicate the financial and socioeconomic effects for each agent. The totals for the rows should show the values calculated in the CBA for the specific effect, which should be zero for cash transfers. An example on the application of the S/E Matrix to a toll motorway is shown in Appendix B.

[11] Figure II-1 shows, with grey background, the cells that are usually relevant in a rail project.

[12] The total financial flows of an effect among the different agents (row totals) should be nil as they represent pure cash transfers (fares, tolls, taxes and payments to builders, operators, etc.).

Figure II-1. Stakeholders/Effects Matrix for a railway project (example)



Source: RAILPAG, (Turró, 2004)

In projects of a certain complexity in which the distribution of the costs and benefits among the agents involved is critical, the redistributive effects among project-linked stakeholders may have strong political and social connotations. The effects of a particular pricing policy, for example, on users, service operators, various administrations and, therefore, groups of taxpayers, are better observed in the synthetic presentation of the S/E Matrix. In these cases, their knowledge, alongside the typical CBA global indicators, can contribute to an improved decision-making process as the results could be used to improve both the financing and the management of the project.

2.2. THE SOCIAL REDISTRIBUTIVE EFFECTS

There exists an open debate about the social effects linked to certain transport infrastructure investments. Quite often public subsidies are necessary to build, maintain and operate these projects. This may be reasonable in terms of efficiency[13] but subsidies represent a transfer of resources from the whole society to users and have effects on income distribution. If the subsidised project will mainly favour users with high income[14], the social impact can be considered regressive. On the other hand, most public transport investments in urban areas would be progressive, as they would benefit more the social strata with lower revenues.

[13] Reducing the generalised user costs entails effects (demand growth) that have to be included into the CBA.

[14] An issue that has been raised, for instance in Spain, due to the large (excessive?) expansion of the high-speed rail network.

Where there are market or information imperfections there is potential for government action to improve the living conditions of citizens. Governments are expected to act, in particular, when market failures entail the inefficient allocation of resources from the Pareto perspective, i.e. when some groups turn out to be adversely affected (Townsend et al., 1988), or simply when free market keeps some members of society with unacceptably low levels of quality of life (according to the accepted rules of wealth distribution) or when there are unused resources (Stiglitz, 1997). Otherwise, equity issues may arise, especially for underprivileged groups lacking access to certain goods and services.

The use of shadow values, also called social or regulatory values, is a method widely used for the inclusion of equity goals of social character within the CBA (DG-Regio, 2015). In principle, the resources mobilised by a project are monetised, when there exists a market for them, by using the price resulting from the law of supply and demand. This price is often difficult to forecast and can vary according to the region and/or the economic situation. However, the existence of market distortions or the application of certain policies by decision-makers may recommend the adoption of shadow values, calculated using real prices corrected to better reflect the usefulness of resources for the whole society. Shadow values, which may be higher or lower than the corresponding market price, are often used, in the social field, in relation to the reduction of unemployment and poverty and with the promotion of equal opportunities (Harris & Kende-Robb, 2008; World Bank, 2013; Ferreira & Peragine, 2015). Of particular interest for transport infrastructure is the use of social values of time (Turró, 1979; Banister & Berechman, 2001; Mackie et al., 2001; de Rus & Nombela, 2007). Using them instead of behavioural values (those explaining traveller choices), which are assimilated to market values, means that those users with low values of time (i.e. in general those with lower income levels) are getting a higher valuation for their time savings than their own judgement. This means that, using single values of time, a rather common practice, means that the CBA incorporates a positive equity bias.

An alternative to the shadow values technique, very controversial, is to recur, into the CBA itself, to the use of certain weighting criteria with the aim of taking into account, implicitly, the preferences of the decision-maker at the moment of accounting the social costs and/or benefits identified in the CBA (Harberger, 1978; Layard, 1980; Gannon & Liu, 1997; Cowell & Gardiner, 1999; Johansson-Stenman, 2005; Johnstone & Serret, 2006). Another possibility, which is the most widespread practice, is to complement the CBA with a multi-criteria decision approach (OECD, 2002). The set of weights is explicitly established in the multi-criteria analysis, reflecting the importance that the decision-maker assigns to the different social aspects. This method entails the double challenge of having to properly link weights and objectives, which sometimes are contradictory, and to produce, at the end, an outcome that can be easily interpreted by the decision-maker (Turró, 2015).

Investment decisions should be justified *ex ante*, taking into account, on the one hand, the net socioeconomic benefits and costs that can be expected by the different social groups affected by the project[15], and on the other hand, the financial balances of the project (for instance, the stakeholders that will have positive and negative FNPVs, as the total cash flows should be zero). Assessing the potential effects of an infrastructure investment on the various social groups affected is a big challenge, but is an essential step in order to incorporate them in a balanced way in the decision-making process. In practice, the profitability principle tends to get priority over the equity principle (Bonnafous & Masson, 2003), which may lead decision makers to reject projects that, however, entail redistributive effects for the targeted social groups that could be valuable enough in monetary terms as to offset the negative ENPV obtained in the CBA.

[15] This first level of redistribution, internal to the project itself, which can be analysed from the Stakeholders/Effect Matrix, has been discussed in the previous section.

2.3. THE TERRITORIAL REDISTRIBUTIVE EFFECTS

Investment is supposed to be a driver of economic development. Public investment is used, in particular, to support wealth creation in certain areas following specific objectives, such as reducing the spread of wealth among regions or promoting certain locations (e.g. the capital of the country, border zones for political reasons). Focusing investment in such places invariably means that it introduces a bias against the areas not benefitting from similar support: it has a redistribution effect on the territory. Regional policy has substantial weight in most political programmes. In the EU the objective of convergence between countries and/or regions is an essential counterbalance to the creation of the Single Market and absorbs a substantial part of the EU budget (Turró, 1999). Governments see investments to improve accessibility conditions[16] as a powerful vector of regional policies due to these redistributive effects.

Traditionally, classical macroeconomic studies have pursued the quantification of the effects of accessibility improvements in terms of growth of the income per capita, by analysing the influence of the investment through variables such as capital stock, employment and productivity (Bruinsma et al., 1996; Stough et al., 2002; Nixon et al., 2018), as well as other factors that depend on technological progress, which is, in the long-term, the ultimate engine of economic growth (Román, 2001; Narváez et al., 2008; Vieira, 2008). Recently, economic models based on spatial analysis, such as the LUTI *(land-use transport interaction)* or the SCGE *(spatial computable general equilibrium approach)* have included indicators of territorial accessibility[17] within their analysis. This allows simulating the indirect economic impacts (wider impacts) of different options of infrastructure development under several socioeconomic and transport scenarios (ITF, 2017). New lines of research are, in addition, making progress by comparing areas that are 'treated' by a transport improvement with areas that are similar but 'untreated' (Redding & Turner, 2014). In any case, economic development is increasingly pursued, at least in the EU, through integrated investments for which transport is only one, albeit relevant, aspect. This makes discrimination of the sole effects of connectivity improvements quite difficult to identify.

In spite of the many caveats that can be raised, it seems obvious that, when travel times get shorter thanks to transport improvements, generalised mobility costs are reduced and social and commercial relationships are favoured. This might disperse the existing economic activity by encouraging capital towards areas benefitting from the market extension (Forkenbrock & Foster, 1990; Ferrer, 1992; Berechman, 1995; Banister & Edwards, 1995). The favourable atmosphere thus created generates jobs in these areas, especially for those with low-income levels (Kain, 1968), with potential negative effects on employment in areas with lower productivity. The development of transport networks, through this mechanism, generates global efficiency following the relocation of economic activities.

Although transport infrastructure is seen as a catalyst for the development of the poorest regions, the real impact will depend on the capacity of the region to take advantage of the new

[16] Accessibility initiatives may be classified in three broad categories according to the project's scope (ITF, 2018): 1) *marginal projects*, which have small and local impacts on thus are irrelevant to make the decision-to-build.; 2) *non-marginal and non-transformative projects*, if there are sources of market failure (e.g., imperfect competition or agglomeration externalities) making the project's wider effects to be important for the decision-making process.; and 3) *transformative projects*, which implies accessibility changes causing wider impacts for regional economy that are significantly different with the project in place that without. For the purpose of this paper, accessibility improvements refer to cases 2) and/or 3).

[17] The quality of the most widely used accessibility indicators is questionable (for instance, the definition of the reference area, such as the national or regional territory). See an interesting synthesis in Litman, (2011) and the arguments behind the proposal of the ICON connectivity indicator (Ulied, 1995). The accessibility indicators used by ESPON, (2017) show the trend towards measuring access to concrete services.

possibilities offered by the increased accessibility. When there is a latent endogenous potential that can be unfolded, direct or indirect (e.g. tourism) exports could become wealth generators. However, without certain complementary assets (other infrastructure, local capital and entrepreneurship, etc.), the new conditions may induce imports and end up having a negative effect on the local economy. So, the sense and the distribution of the effects of improved transport infrastructure on the regional development are not clear and surely not evenly distributed along the areas affected, because this depend on their zones of influence and both the characteristics of its access points and the initial competitive-situation of the populations affected (Fariña et al., 2000).

The economic science has not yet found a proper formula to estimate the location and magnitude of the impacts linked to changes in accessibility (Oosterhaven & Elhorst, 2004). Measuring actual traffic is the most concrete and foolproof gauge of the actual benefits of a transport project (Ansar et al., 2016). It could be argued that “the more users, the more value is derived by those users” through network externalities (Röller & Waverman, 2001), and in the case that direct productivity effects are found to be weak (or not found) the macro-studies are able to defend indirect benefits through spillover effects (Ansar et al., 2016). However, where wider positive impacts exist, they could be offset by negative impacts in other regions (Vickerman, 2017). At the microeconomic level, network impacts are even more difficult to identify. In traditional CBA, a working assumption is that the user benefits reflect all the benefits of transport in the case of perfect competition (Boardman et al., 2017; ITF, 2017), which implies that, beyond the value of benefits calculated in CBA, which include, for instance, those of induced traffic, there is not additional value to be gained in the economy from the wider impacts resulting from new transport infrastructure investment (OECD, 2002; Beuthe, 2002; Mackie et al., 2011). But what can actually be observed is that the efficiency benefits included in the CBA often generate effects on the economic system –non-transport benefits or development benefits– that are not incorporated in the standard efficiency calculations (ITF, 2018). These additional benefits may be especially important in certain areas located next to new transport infrastructure (Hess & Almeida, 2007; Mulley, 2014; Venables, 2015; Higgins & Kanaroglou, 2018). If such externalities (development effects) are important to make the decision-to-build, they should be properly identified and distinguished from “efficiency benefits” to avoid double counting (OECD, 2002; ITF, 2017).

Under the assumption of the development effects of accessibility improvements, it is logical that investments in transport infrastructure be used to pursue objectives of spatial equity[18] (Rietveld, 1989; Banister & Berechman, 2001; Oosterhaven & Knaap, 2003; Hensher et al., 2012; Myung-Jin, 2012). Such objectives indicate that regional policy designers are fully aware of the territorial redistributive effects of transport investments, which have traditionally been used to reduce disparities among regions (ITF, 2018) on the base that public investment in infrastructure is an exogenous cost-reducing technological input into the economy (Krugman, 1991; Holtz-Eakin & Lovely, 1996; Glaeser & Kohlhase, 2004). There is, nevertheless, an increasing body of knowledge about the potential of such actions to trigger territorial and social inequalities[19] if public administrations do not take appropriate measures concerning other aspects, including on education, the labour market, urban development and social housing, etc. (van Dijk, 2016; ITF, 2018).

[18] Spatial equity studies seek to establish whether or not all individuals may access the basic services provided in a territory and if they have freedom of movement within it.

[19] Accessibility conditions are often central for spatial bifurcation (segregation phenomena) between income groups (Atkinson, 2006)

Table II-1. Typologies of the territorial redistributive effects stemming from transport infrastructure investment

TERRITORIAL REDISTRIBUTIVE EFFECT		TRIGGER FACTOR	DESCRIPTION
SHORT TERM	Industrial competitiveness (exports) effects	Logistic costs reduction	Only sub-territories with high productivity levels or very low production costs may expand quickly their exports following lower transport costs.
SHORT TERM	Direct socioeconomic impacts of the main investment	Direct economic impacts of project construction	It will depend on the location of the economic agents directly involved in the construction. Workforce and materials used in the project may come or not from the region. The actual redistribution effects (site jobs, services to the construction companies, etc.) will depend on how much the different sub-territories get from the investment.
MEDIUM TERM	Reorganisation/relocation of socioeconomic activity due to displacement and generation of new activities	Accessibility improvements	Transport costs reduction may entail positive impacts through market extension and scale economies. This should attract complementary investments and consequent productivity improvements and second-degree effects on employment and wealth generation. It will, however, have negative effects through the destruction of non-competitive industries. The final impact will depend on the ability of the endogenous industrial fabric of each sub-territory to take advantage of the new opportunities, which will depend on availability of capital, qualified labour, etc.
MEDIUM TERM	Tourism flows redistribution [20]	Reduction in transport costs and improved travel conditions	Attracting tourists will depend on both the accessibility conditions and the tourism potential (landscape, cultural heritage, etc., but also tourism infrastructure) of each sub-territory. Often, complementary investment will be needed to benefit from the project.
LONG TERM	Wider economic benefits	Second level of economic spillovers (externalities) stemming from the project	Long-term effects of creative destruction (elimination of non-competitive activities and creation of new ones where there is a competitive advantage). Incentives to improve capacities (education), to retain talent, to innovate, etc.

Source: Author

Table II-1 presents a set of typologies identifying the most relevant territorial redistributive effects that respond to the moment when the redistribution effects will probably be perceived in the territory. They arise from the impact of the project on the equilibria explaining the specific social and economic development situation of a particular region (Puga, 2002; Combes & Lafourcade, 2005; Teixeira, 2006; Ulltveit-Moe, 2007). This impact will essentially depend on the location, in relation to the project, of the economic agents in the geographical area, on its organisation/governance, as well as on the structural determinants of regional productivity[21] (ITF, 2018). The macroeconomic measures that are typically used to obtain metrics on the expected economic impact on the local economy, such as the value of the infrastructure assets lying within the local area or job creation, are clearly poor indicators of potential growth[22], but

[20] It can be argued that "tourism redistribution" should be considered in Table II-1 as part of the 'reorganisation/relocation of socioeconomic activity'. However, tourism investments are quicker to appear, as they tend to be relatively smaller and do not require the same know-how of industrial ventures or more sophisticated services. Showing tourism effects separately facilitates their identification for further analysis.

[21] In general, the factors that determine labour productivity can be divided up in three broad categories: knowledge-based capital, physical capital and human capital (ITF, 2018). The effects of a transport infrastructure project mostly affect the second category, but indirectly affect the other two.

[22] To give an example of this, see the impact of a high-speed rail line crossing a less developed area between two main cities and no station in it (as there is not sufficient demand). The infrastructure only produces negative

the identification of better regional development indicators falls beyond the objectives of this paper.

In principle, the project's territorial redistributive effects should be only considered as positive if they imply a positive net-balance in terms of resources (ENPV>0) for the region for which the analysis is performed. Even so, in major transport projects there is inevitable a confluence of different levels of government, each one possibly with particular objectives of political and economic character that could even be in conflict. Improved accessibility conditions could even be considered negative by some administrations (in general, local ones) if they do not favour socioeconomic activity in their territory. The point is whether the changes due to new accessibility conditions imply an improvement of the competitive position of every sub-territory, or whether some of them will clearly benefit from the project but at the expense of others (due to relocation phenomena). In terms of territorial redistribution effects, it could even be interesting to analyse if the project could involve a certain degree of reorganisation of the activity of the social and economic agents within the sub-territory itself.

The spatial effects of a transport infrastructure project may, therefore, be important and affect different areas over time in substantially distinctive ways. Given the close relationship between decision-makers (politicians) and the territory, as elections are held according to administrative boundaries, territorial redistributive effects are surely of major importance in the investment decision process. The definition of clear indicators for the expected economic development effects of transport infrastructure projects should therefore improve the quality and fairness of the process.

2.4. THE ENVIRONMENTAL REDISTRIBUTIVE EFFECTS

The environmental impacts of transport affect people and nature, in general, in a multiplicity of forms and, as a consequence, they are unevenly distributed. The most obvious and better-known formulation of environmental redistribution is linked to the territorial scope of the impacts. Some of the impacts, such as land occupation or nuisances during construction, are linked to the infrastructure; they are essentially local and, at least for those produced by the works, quite time-bounded. Most of the heaviest impacts of transport projects are generated, however, by the activity that takes place on this infrastructure during a long operation period. Some of them, such as acoustic pollution (noise) or barrier effects are clearly local, but other impacts, including air pollution, have a diversity of spatial footprints. Measurement and territorialisation of environmental impacts is complex and their valuation particularly difficult[23]. A clear example of this difficulty may be found in greenhouse emissions, which have global effects but clearly different implications for certain world areas[24]. So, depending on the geographical area concerned by the environmental impact of the project, it is possible to classify the environmental redistributive effects as:

externalities, whilst most job creation (consultants, producers of sleepers, tracks, electrification and signalling systems, rolling stock, etc.) takes place elsewhere. Only a few (small) local construction and service companies will really generate jobs and mostly during the relatively short construction period. However, decision makers will argue the interest of the project on the assets and jobs generated…

[23] Some of the more common references for environmental values used in transport CBAs, such as INFRAS, (2014) or ExternE (2005), are being questioned by new studies on the long-term health effects of the different pollutants (Mueller et al., 2016; RCPCH, 2016).

[24] Coastal areas, for instance, may be extremely affected. On the other hand, a recent IMF study (Parry et al., 2018) shows the different impact that taxes on CO2 production (considered the most effective way of achieving the Paris agreements) would have in different countries. But the potential use of the tax revenues to compensate affected people has not been addressed…

- Local: Mainly those produced by the degradation of both the pre-existing comfort conditions of the population and the quality of the natural environment near the transport infrastructure. Transport infrastructure is essentially linear, producing a "barrier effect" that may impede the movements of many species and, as a consequence, restrict their spatial distribution, with biodiversity impacts. The barrier effect obviously affects also human populations that suffer from restrictions to their movements. Besides the environmental effects of the transport infrastructure itself (land occupation, landscape impact, waste generation, etc.), a transport infrastructure may result in land use changes, with a derived environmental impact. On the other hand, construction works typically generate environmental problems for local inhabitants as they produce inconveniences, including noise, vibrations, dust and air pollution. After commissioning, the operation of the project generates sustained impacts for the local population (noise, vibrations, air pollution[25] but also safety hazards) that may represent major health problem, especially in dense areas of big metropolises and for the elderly and the children.

- Regional: Here are considered the broadest repercussions of the project on ecosystems and the consequences of the impact on biodiversity degradation and on their ability to produce resources. Most regional effects are produced by the operation of the transport infrastructure through more diffuse air pollution (O3, NOx, SOx...) having an indirect impact on human health and on nature. The acidification of soil and water through acid rain and other biophysical effects (e.g. smog) damaging crops and properties are having a variety of effects that depend on the characteristics of the region.

- Global: Those caused by the direct contribution of transport projects to climate change. Fossil fuel consumption during construction works but, in particular during operation, directly (most automobiles) and indirectly (combustion-based electricity generation), is producing greenhouse gases. Once in the atmosphere, these emissions contribute to global warming. Some transport emissions also contribute to ozone layer depletion, although with much less intensity than those of other sectors, so carbon emissions associated to each project may thus be used as a measure of the global effects of a transport investment.

Environmental effects of investments in transport infrastructure are, thus, unequally distributed over the territory. This unequal distribution is often related to social characteristics such as income, social status, employment and education, but also non-economic aspects such as gender, age or ethnicity (WHO, 2010). As a consequence, the environmental damages (costs) may have both territorial and social redistribution effects. On the other hand, some environmental will be virtually instantaneous, such as noise, whilst others, such as CO2 emissions, might last indefinitely, with difficult to predict consequences. Certain environmental externalities have, therefore, an intergenerational redistribution nature.

In the calculation process of socioeconomic profitability, the externalities identified in the environmental impact assessment (EIA) are monetised and incorporated to the CBA as annuities, which are discounted using an "appropriate" discount rate (Henderson & Bateman, 1995; HM Treasury, 2003; Evans & Sezer, 2004; Leleur et al., 2007; Meunier et al., 2013). However, it is not evident that typical social discount rates (SDRs) used in CBA or even the discounting mechanism itself are appropriate to deal with long-term environmental impacts as, under exponential discounting, the costs and benefits accruing to generations in the distant future

[25] In the European Union, environmental quality standards (EU Environmental Noise Directive 2002/49/EC and EU Air Quality Directive 2008/50 EC) appear to have been useful to enforce local governments to have pollution problems under control.

appear relatively unimportant in present value terms (Arrow et al., 2013). Other environmental effects, such as the contribution to climate change of the traffic emissions stemming from the project, which may imply heavy redistribution issues in the future, may be introduced in the economic evaluation through the use of shadow values for CO2 emissions (Pearce & Nash, 1981; Jorge-Calderón & Johansson, 2017). These values may be designed to avoid the SDR effects or even to increase over the project cycle, but this assumes giving values to future impacts that are very difficult to foresee[26].

The permanent environmental effects (biodiversity degradation, global warming impact, etc.) have raised questions on intergenerational[27] equity (Groom et al., 2005; Lowe, 2008; van Wee, 2012; Priemus & van Wee, 2017; Rasch & Köhne, 2017), in line with Rawls' concept of "equity as justice". Indeed, distant generations could end up enduring much of these delayed environmental effects while gaining minimal benefits from the activities, including transport, that are contributing to their production (Wade-Benzoni et al., 2008). As a consequence, from the perspective of the sustainable development, it is necessary to consider, besides the environmental externalities identified in the EIA, which tend to focus on the direct impacts of the transport infrastructure, those spatial and intergenerational effects resulting from the expected activity generated by the project[28].

2.5. THE INTERGENERATIONAL REDISTRIBUTIVE EFFECTS

Social welfare depends, in part, on the ability of governments to obtain affordable funds from the financial markets. The availability of these funds allows GPIs to carry out their policies earlier and more efficiently provided that the benefits obtained from the fast implementation of the project, as generator of long-term wealth, outweigh the costs for society of committing future financial flows to the project. The funding pledge entails that additional public debt will be raised, if the project is fully public, or that the budgets of the GPI and eventually other administrations will have to include the payments envisaged in a PPP[29]. It is obvious that financing represents a critical aspect in the design and implementation of a major project. It is also obvious that it is a complex exercise that must balance actual payment commitments with expected revenues that may depend on outcomes, such as user fees, that are quite difficult to foresee. It is thus an exercise that must be adapted to the long-term character of transport infrastructure and show a certain degree of flexibility to cope with forecasting errors. Both aspects are essential to ensure the financial sustainability of the project, i.e. the capacity to deal with reasonable risks without having a major stakeholder unable to comply with its financial commitments.

[26] Besides, as a CBA requires defining the social frame for which the analysis is executed (often coinciding with the GPI's citizens), this implies valuing how global impacts happening outside the remit of the concerned "society" are incorporated as resources in the CBA.

[27] Intergenerational equity typically refers to achieve a fair, ethical balance of costs and benefits between present and future generations (Rawls, 1972; Daniels, 1988; Barnes & Lord, 2017). In the environmental context, topics on intergenerational issues include global warming, climate change, exhaustible resources and diversity of species (United Nations, 1987). In a socioeconomic context, intergenerational issues refer to age-related expenses (Thompson, 2003; Williamson & Rhodes, 2011) infrastructure provision and/or fiscal equity (McCrae & Aiken, 2000). In the context of major projects procurement, it essentially refers to country debt or the taxes that will need to be paid by future generations to meet the costs of present investment (Jim & Love, 2011).

[28] The CBA should incorporate, in its annuities, the monetised environmental impacts of the project, but this is not done systematically and the impact of long-term outcomes is severely mitigated by the use of the SDR.

[29] A PPP that generates income for the public sector, for instance through concession fees, should not entail postponements due to budgetary constraints.

Transport infrastructure is typically carried out by the public sector, which means that it is the taxpayer who foots the bill. This often implies to have recourse to external sources of funds, usually through credit institutions, to complement and extend the money that the GPI assigns in its annual budgets to cover the instalments –usually made during the construction period– to pay those agents, mostly private, executing the project (Vickerman, 2004). Financing instruments, such as specific bond issues or loans, allow spreading the actual financial burden on taxpayers over many years, but it is worth noting that they have a clear impact in terms of public debt and may represent a certain opportunity cost[30] for society. Recent research suggests that debt-financed overinvestment contributes to underperformance and instability in the economy because poor project-level outcomes translate into substantial macroeconomic risks (Ansar et al., 2016; ITF, 2018). Public-private partnerships (PPPs) in general, and long-term concessions in particular, have been presented as a solution to public investment constraints. They may be so when no public contributions are foreseen –international accounting rules are very restrictive in this sense– but, in any case, irrespective of the financing mechanism used, infrastructure projects must be properly justified.

The justification is provided by the beneficiaries of the project. The users and, generally, the society "of each moment", which can be referred as a generation[31], perceive these benefits. On the other hand, the same users, through payment for its use, and the taxpayers that contribute to the project instalments in the budget are those who actually pay the investment. These benefits and the financial flows may or may not be aligned. Whilst some (annual) generations may benefit more than their financial contributions, others may end up bearing the financial burden without receiving sufficient net benefits in return. This would imply redistributive effects among the generations affected by the project (Penyalver & Turró, 2017) and could be substantial depending on the financing formula finally adopted. Checking on such differential impacts and, in particular, the tendency to benefit or adversely affect future generations should be included as a factor in decision-making, especially when deciding the financial structure to be adopted for the project (Turró & Penyalver, 2019).

So far, however, the relation between short-term and long-term impacts is considered mostly through the discount rate and, in some cases, in relation to environmental effects[32]. Discount rates are a key element in the calculations of CBA criteria (i.e. net present value) as the higher the value the greater the importance given to the present at the expense of the future. This distortion is even more pronounced when the economic rate of return (ERR) is used[33] as the main reference of the project's convenience for society. Discount rates severely affect public policy and investment decisions and their use and values are obviously not free of some controversy (HM Treasury, 2003; Meunier et al., 2013). On the other hand, it is not evident at all how its formulation may reflect certain aspects of the individuals' economic-behaviour, in particular those regarding long-term or intertemporal preferences. The fairness towards "our

[30] This cost is more evident in highly indebted countries, where debt restrictions entail a serious handicap for any GPI to develop "productive investments", meaning investments enhancing long-term growth. In the EU, for instance, national governments must comply with the rules of the Stability and Growth Pact (SGP), created with the aim to keep public debt sustainable.

[31] Since Mannheim's "The problem of generations" (1923), the concept of "generation" or "social generation" has been used in the sense of "cohort", which refers to people within a delineated population who experience the same significant event within a given period of time (Pilcher, 1994). But the concept of "annual generation", which refers to the group of individuals affected by the effects of a major transport infrastructure project over time, is more explicit, as defines the number of years (or timespan) included in the (social) generation and allows representing the individuals' preferences on such effects through a survey-based weighting curve (Penyalver et al., 2018).

[32] Separate discount rates for these effects are sometimes used. The values of greenhouse gases take into account their long-term impact and represent an indirect way of considering intergenerational issues.

[33] The better the projects (i.e. the higher the ERR), the lesser are the long-term effects in the results.

children", an ecologist mantra, is often used to justify politically certain projects that are probably inefficient. From the review of appraisal guidelines and the analysis of a number of practical cases, it can be argued that, in spite of the emphasis that many politicians place in the wellbeing of future generations, the procedures presently used in major transport project appraisal are not including any adequate measure of their intergenerational implications (Turró & Penyalver, 2019).

This inadequacy is even more striking when the financial analysis is included in the process. The socioeconomic CBA is supposed to monetise the costs and the benefits incurred each year in terms of resources. However, while the benefits are mostly perceived by those belonging to the society of the year in question, the costs in resources foregone during a specific year are quite often the object of financial transfers. In particular, the resources foregone due to the construction works entail payments by the GPI to the construction companies often using loans that are repaid over a long period. This "money transfers" are not relevant for the socioeconomic CBA because they are assumed to occur within the same society. But this is a false premise because the members of society change over the years (ISR, 2017). When these transfers are important the hypothesis behind the CBA does not hold and it is reasonable to check if these transfers represent substantial intergenerational effects[34].

The above arguments justify the convenience of performing a proper assessment on the intergenerational impact that the "money transfers" stemming from the project's financing formula entail for the whole of society over the project lifecycle (Penyalver & Turró, 2017). The efficiency criterion should be always the main concern of decision makers, but the analysis of the intergenerational impact is particularly relevant for major transport infrastructure projects due to the amount of funds involved as well as their long life cycle. The effects of the financing formula of a specific project for the public sector are obviously embedded in the global macroeconomic context[35] and it could be argued that the effects of the total public debt are those really relevant for future generations. But the implications of the marginal increase in public debt brought about by a project are not our concern here. What is important within the decision-making process for a major project is to generate awareness of all the implications that are relevant for society and, if possible, to provide indicators allowing a proper assessment of the implications.

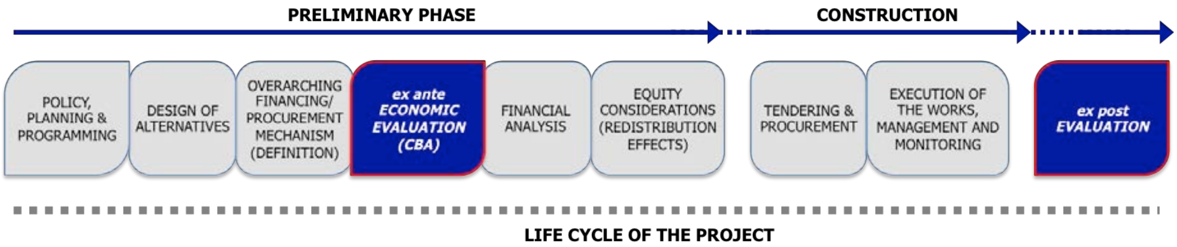
3. INCORPORATING REDISTRIBUTIVE EFFECTS IN DECISION-MAKING

As stated, the theoretical decision-making process of the public sector for transport infrastructure provision should always be justified, at least theoretically, on basis of the socioeconomic efficiency of the investment, usually assessed from the CBA outputs. However, the "global" analysis of costs and benefits does not always lead to the most adequate solutions, as the population expects decision-makers to take into account certain objectives that transcend CBA. In this sense, it seems adequate that such objectives, quite often related to equity and thus to redistribution, which typically is not part of the CBA exercise, be made explicit and, if they obey to a democratically decided programme, be incorporated in the overall decision-making process (cf. Figure II-2).

[34] An efficient intergenerational allocation would depend on the resources available to each generation (Padilla, 2001).

[35] The limits on public deficit and debt imposed to the national governments of the Eurozone constitute a severe constraint on investments. The benefits and costs of these limitations would deserve a proper analysis, including in terms of intergenerational fairness.

Figure II-2. Decision-making process for major transport infrastructure projects



Source: Author

Most public policies defend indeed a bias in favour of a certain area, social group or specific agents (Henisz & Zelner, 2006), such as public companies, even though the equity goal itself is often vague (Martens et al., 2012). In some instances, redistribution effects seem to be the only real argument for certain investments (Turró & Penyalver, 2019). Accordingly, redistribution effects must be clarified to ensure policy compliance and fairness, as equity considerations may potentially be used as a pure qualitative argument to justify investment decisions that may be controversial from the traditional economic perspective (Manaugh & El-Geneidy, 2012). How to incorporate redistributive effects in the decision-making process is actually an open question (Khraibani et al., 2016), though, in any case, the biases they introduce should be measured and put in perspective. In this sense, their identification according to the classification here proposed (cf. Table II-2) should facilitate their inclusion in a more transparent decision-making process.

The typologies defined here are expected to cover most of the redistributive effects generated by transport investment that could be openly considered by decision-makers, though certain direct effects identified in a first count might thereafter generate other impacts (second-order effects) as they are often subject to complex interrelationships. In Spain, for instance, the national government is building a high-speed railway network (AVE) with the stated purpose of connecting every province capital of the country with Madrid in less than four hours[36]. It is clear that the political objective of territorial redistribution –in this case to support a strong centralisation process– would have a parallel, secondary effect, at the regional level as the high-speed railway (HSR) system essentially serves the main cities along the HSR lines and much less the other urban and rural areas (Givoni, 2006; Albalate & Bel, 2012). Without discussing here the obvious inefficiencies of the "plan", there are clear winners (e.g. certain construction companies) and losers (e.g. domestic airlines) among the stakeholders in these projects, and also social redistributive effects, as HSR users are mostly from the higher income groups (Albalate & Bel, 2012). Furthermore, HSR projects could entice environmental redistributive effects. They make medium-distance transportation more environmentally friendly[37] while the impacts on landscape and the barrier effect are mostly suffered by rural populations that have few opportunities to take advantage of the high-speed services (Albalate & Bel, 2012).

[36] This target was declared by Jose Maria Aznar in the programme for his second term of office as president of the Spanish government that was presented to the Parliament (April 25th, 2000).

[37] High-speed rail is predominantly electric powered, which means virtually zero emissions from the HSR along the line and at the stations, typically located at the centre of main cities (Givoni, 2006). Besides, as power plants are typically located away from densely populated areas, emissions from HSR operations occur far away from cities.

Table II-2. Identification of the redistributive effects of major transport infrastructure projects

DESCRIPTION			KEY ELEMENT TO IDENTIFY IT	AGENTS CONCERNED
CHARACTER OF THE REDISTRIBUTIVE EFFECT:	INTERNAL: AMONG STAKEHOLDERS	Those due to the sharing of costs and benefits linked to the project that are taken into account globally in the CBA, but which affect differently the various agents involved in the project.	Classification of the agents directly involved in the project. Stakeholders/Effects Matrix.	The SE Matrix should include all relevant agents in the project: various types of users, operators, public administrations, construction companies, land owners, etc. If there are major imbalances amongst them, they should be highlighted.
	SOCIAL	Those occurring as a result of how the benefits and costs are distributed amongst the relevant social groups.	Distinction among social groups, both positively and negatively affected by the project.	Certain social categories or market segments may be affected differently by the project. They are usually defined by social characteristics: household income level, gender, age, vulnerability (unemployed, marginalized, etc.), but could include other grouping factors (Nymbies, health condition, etc.)
	TERRITORIAL	Those that have clear differential affections to certain areas, both physical or economic. Social and environmental impacts are often territorial, but the focus here is on local effects that are not included there and on the biases introduced on economic activity due to the changes in accessibility conditions.	Delimitation of the territorial reference unit, which depends on the project scope and on administrative boundaries. Identifying the factors that determine the endogenous development potential of the territorial unit.	In principle, all citizens and economic activity within the territorial units. Traditional macroeconomic indicators (GDP/capita, productivity, employment, productive sectors distribution, etc.) may be used to assess the impacts of the project.
	ENVIRONMENTAL	Those due to environmental impacts showing clearly differential effects on specific groups of people or areas.	Distinction of the environmental effects of the project in function of their local, regional or global repercussion.	On a local scale, the area next to the transport infrastructure in which noise, vibrations and other proximity impacts are concentrated. On a regional scale, the area suffering from diffuse effects, notably from air pollution. On a global scale, the effects caused by the contribution of transport projects to greenhouse gases emissions.
	INTERGENERA-TIONAL	Those arising if the actual payments over time envisaged by the financing of the project are not aligned with the net socio-economic benefits that the society "of each moment" receives.	Annuities of the net socioeconomic benefits. Financing formula linked to the life cycle of the project. The IREM model can provide indicators.	Users and taxpayers belonging to “annual generations” who end up paying for the project. They may be linked to specific areas or social groups.

Source: Author

The most widespread practice to incorporate redistribution effects (and possibly other policy objectives) alongside efficiency in the decision-making process is to complement the CBA with some form of multi-criteria analysis through a set of weights explicitly established (Beira et al., 2012; Weisbrod, 2015; ITF, 2017), which should reflect the importance that the decision-makers assign to efficiency and to the other criteria. These other criteria are, in general, more difficult to justify[38] so, ideally, the weighted combination of the redistributive effects that are typically matched to policy objectives –in principle, those of territorial, social and environmental nature– should be valuable enough, in monetary terms, as to offset the negative ENPV obtained in the

[38] They could be purely political (i.e. election-driven), to support some macroeconomic policies or even responding to spurious interests. In most cases such criteria would not be made explicit in a multi-criteria analysis.

CBA or, if the ENPV is positive, their combination (overall negative) should not be considered sufficient to outweigh the estimated efficiency of the project. A main challenge of this procedure is, of course, to avoid double counting, in particular when the CBA includes positive externalities, such as environmental impacts or other indirect effects that could be replicated in the relevant redistribution analysis. For example, the increase in land value locally as a consequence of accessibility enhancements is a typical (indirect) effect included in the CBA. Assuming the existence of a perfect market, such increase would lead, in turn, to a decrease in the real estate value elsewhere. This means that, in the long run, some territorial redistributive effects that are seldom included in the CBA will take place, at least explicitly[39]. In this case, an experienced analyst should offer a clear picture, easy to interpret, of the redistribution issues stemming from the project, which should allow to value, also in monetary terms, the measures that will be necessary to counteract/offset such differential impacts and, if necessary, other (negative) impacts of second order that may be envisaged[40] from the redistribution effects identified in a first count.

The CBA, on the other hand, rarely pays the required attention to the final financing formula of the project. It is clear, though, that the participation of the private sector, for instance through a public-private partnership, has obvious implications on costs, demand and other aspects that should be considered in the ex-ante appraisal (Vining & Boardman, 2008; Vinning & Weimber, 2015). In this sense, strong biases, which can be identified in the project's SE Matrix, might have a significant impact on the technical definition of the project, on its profitability and doubtless on its financial sustainability (Turró & Penyalver, 2019). Besides this consideration on the financing structure, which is based on a "present" view of the socioeconomic and financial flows, the intergenerational effects related to the time when project costs are actually paid, according to the adopted financing formula, deserve special attention because, in projects with long technical life, there is always a potential unbalance between the project's socioeconomic net benefits, identified in the CBA, and the financial contribution (Ascher & Krupp, 2010), through user payments and/or taxes. The *Intergenerational Redistributive Effects Model* or IREM (Penyalver & Turró, 2017) may be useful in these cases to provide insights on whether the financial structuring is fair for the (overlapping) annual generations affected by the project along its lifecycle (Turró & Penyalver, 2019). As future generations cannot directly influence the policies being chosen today, equity considerations require paying attention to potential intergenerational redistribution effects when making the decision to build.

In short, investment decisions are quite often driven by other considerations than efficiency (OECD, 2002; Winston, 2006; Henisz & Zelner, 2006), which may be reasonable or not, but should, in any case, not lead to the GPI to engage in projects that could be inefficient, financially unsustainable or that could endanger the capacity of future generations to cope with their financial implications. In this sense, the identification of the project's redistributive effects may be useful to both generate awareness and interest concerning the wider impacts of major investments beyond the expected socioeconomic profitability.

[39] Some practitioners could argue that the monetary value for the increase in land value used in the CBA is made taking into account such phenomenon (redistribution issues) implicitly. Although such argument is weak, in any case, the "net" land value envisaged for the CBA should be justified explicitly, in principle, from the analysis and the economic valuation of the actions needed to counteract the negative impacts of the project on the real estate market elsewhere.

[40] Following the former example, strong territorial redistributive effects resulting in significant land value uplifts next to the infrastructure could potentially expel some groups of individuals (in principle, those with less resources) towards more deprived areas, usually with poorer connectivity conditions to the public transport network. An indirect social redistribution effect might be expected.

4. CONCLUSIONS

Major projects of transport infrastructure have a great political visibility because they mobilise a huge amount of economic resources over the years and have significant social, territorial and environmental effects and concern multiple generations. Usually, the CBA method is used to evaluate the socioeconomic profitability of these projects. Nonetheless, from the CBA's outcomes it is not possible to obtain information about which social groups will benefit from the investment and which others will bear its costs. The CBA does not offer a proper acknowledgement of winners and losers whilst it is clear that any major project entails clear redistribution effects.

At the microeconomic level the investments in transport infrastructure projects should only be promoted when backed by a rigorous CBA ensuring sufficient added value for the overall society. Even so, if the redistribution effects are strong, they may generate serious opposition by those sectors/groups negatively affected. In this sense, the S/E Matrix has proven to be useful to identify, among the various agents involved, who benefits the most from the project and who is negatively affected by it. The analysis of this type of redistributive effects may offer valuable insights on the political and social connotations that, in particular in the transport sector, are critical for the investment decision.

Besides the differential impacts on stakeholders, those of territorial, social and environmental nature should also be identified, in this case by means of a thorough analysis of redistribution effects. These effects are often pursued by the GPI as part of pre-determined political objectives that are very often interlinked, so a major challenge for project analysts will be to avoid double counting. Their challenge will be to assess if their combination would be strong enough to change the sign of the socioeconomic efficiency (i.e. ENPV) of the project. The comparison of the redistribution effects with the economic value of the project, in money terms, should provide the decision-maker with a solid indicator of its real interest.

The financial structuring linked to the investments that the society "of each moment" requires also has its importance. One of the elements of which depends on social welfare is the ability of governments to obtain funds to carry out their policies, especially the most indebted States, where much of the wealth generated each year is devoted to the repayment of public debt. At the macroeconomic level, it is extremely important to keep under control the balance between, on the one hand, the effort made by population when economic resources are set aside from current consumption to support this debt, and on the other hand, the profit that society will get in the future from borrowed resources. At microeconomic level, the intergenerational redistributive effects from investment in major transport infrastructure project are a specific redistributive effect due to the variability, across the different generations affected by the project, of the financing gap between what they will pay and the benefits they will obtain. However, intergenerational transfers are often neglected as it is assumed that the resources consumed and generated across the project's lifespan will concern to individuals belonging to the decision-makers' generation.

Leaving aside the repercussion of redistributive effects on the overall efficiency, the impact of their intensity and sense should be taken into consideration. The classification proposed in this paper will facilitate giving to each redistributive effect a proper weight within the decision-making process, which will thus be able to incorporate equity purposes in a more systematic way. It will also be useful to detect when there is a risk that the potential repercussions of the redistributive effects differ or contravene the mandate of policy-makers and is therefore necessary to take prevention or mitigating measures.

5. REFERENCES

- Albalate, D. & Bel, G., 2010. Cuando la Economía no Importa: Auge y Explendor de la Alta Velocidad en España. Economía Aplicada, (54). Sección Observatorio.
- Albalate, D. & Bel, G., 2012. High-speed rail: Lessons for policy makers from experiences abroad. Public Administration Review, 72 (3), 336-349.
- Ansar, A., Flyvbjerg, B., Budzier, A. & Lunn, D., 2016. Does infrastructure investment led to economic growth? Evidence from China. Oxford Review of Economic Policy, 32(3), pp.360-90.
- Arrow, K.J. et al., 2013. Determining Benefits and Costs for Future Generations. Environmental Economics, 341, pp.349-50.
- Ascher, W. & Krupp. C., 2010. Distributional implications of alternative financing of physical infrastructure development. In Physical Infrastructure Development: Balancing the Growth, Equity, and Environmental Imperatives (pp.35-68). Palgrave Macmillan, New York.
- Atkinson, R., 2006. Atkinson, R. (2006). Padding the bunker: strategies of middle-class disaffiliation and colonisation in the city. Urban Studies, 43(4), pp.419-832.
- Banister, D. & Berechman, J., 2001. Transport investment and the promotion of economic growth. Journal of Transport Geography, 9(3), pp. 209-218.
- Banister, D. & Edwards, M., 1995. Measuring the Development and Social Impacts from Transport Infrastructure Investment: The Case of the Jubilee Line Extension in London. London: Bartlett School of Planning, UCL.
- Barnes, K. & Lord, B., 2017. Intergenerational Equity: Treatment of Infrastructure in Nez Zealand Local Government Financial Planning. Financial Accountability and Management, 33(2), pp.0267-4424.
- Beira, P., Maltese, I. & Mariotti, I., 2012. Multicriteria versus Cost Benefit Analysis: a comparative perspective in the assessment of sustainable mobility. European Transport Research Review, 4, pp.137-52.
- Berechman, J., 1995. Transport Infrastructure Investment and Economic Development: A Review of Key Analytical and Empirical Issues. London: Chapman and Hall.
- Bermejo, R. & Hoyos, D., 2016. Análisis transdisciplinar del modelo ferroviario de alta velocidad: el proyecto de Nueva Red Ferroviaria para el País Vasco. Working Papers (71). Universidad del País Vasco UPV.Instituto de Estudios sobre Desarrollo y Cooperación Internacional.
- Beuthe, M., 2002. Transport evaluation methods: from cost-benefit analysis to multicriteria analysis and the decision framework. Project and Policy evaluation in Transport, pp.215-43.
- Beyazit, E., 2011. Evaluating Social Justice in Transport: Lessons to be Learned from the Capability Approach. Transports Reviews, 31(1), pp.117-34.
- Blumenberg, E.A., 2002. On the way to work: welfare participants and barriers to employment. Economic Development Quarterly, 16(4), pp.314-25.
- Boardman, A.E., Greenberg, D.H., Vining, A.R. & Weimer, D.L., 2017. Cost-benefit analysis: concepts and practice. Cambridge University Press.
- Bonnafous, A. & Masson, S., 2003. Assessment of Transport Policy and Spatial Equity. Revue d'Economie Regionale et Urbaine, 4, pp.547-72.
- Bruinsma, F.R., Rienstra, S.A. & Rietveld, P., 1996. Economics Impacts of the Construction of a Transpor Corridor: A Multi-level and Multi-approach case study for the Construction of the A1 Highway in the Netherlands.
- Combes, P.P. & Lafourcade, M., 2005. Transport costs: meausures, determinants, and regional policy implications for France. Journal of Economic Geography, 5(3), pp.319-49.
- Cowell, F.A. & Gardiner, K., 1999. Welfare Weights. Report. UK Office of Fair Trading.
- Daniels, N., 1988. Am I my parents' keeper?: an essay on justice between the young and the old. Oxford University Press.
- de Rus, G., 2009. La medición de la rentabilidad social de las infraestructuras de transporte. Investigaciones Regionales (Sección Panorama y Debates), 14, pp.187-210.
- de Rus, G. & Nombela, G., 2007. Is investment in high speed rail socially profitable?. Journal of Transport Economics and Policy, 41(1), 3-23.
- DG-Regio, 2015. Guide to Cost-Benefit Analysis of Infestment Projects. Economic appraisal tool for Cohesion Policy 2014-2020. Brussels, Belgium: Directorate-General for Regional and Urban Policy of the European Union.

- ESPON, 2017. European Policy Orientations on Territory Development. Database Portal. Available online at: https://www.espon.eu/programme/espon/espon-2020/high-level-workshop
- Jorge-Calderón, D. & Johansson, P.-O, 2017. Emissions Trading and Taxes: An Application to Airport Investment Appraisals. Journal of Transport Economics and Policy, 51(4), 249-265.
- Evans, D. & Sezer, H., 2004. Social discount rates for six major countries. Applied Economics Letters, 11, pp.557-60.
- ExternE, 2005. Externalities of Energy. Methodology 2005 Uptdate. Directorate-General for Research Sustainable Energy Systems of the European Union.
- Fariña, J., Lamíquiz, F. & Pozueta, J., 2000. Efectos territoriales de las infraestructuras de transporte de acceso controlado. Cuadernos de Investigación Urbanística.
- Feldman, A.M. & Serrano, R., 2006. Welfare economics and social choice theory. Springer Science & Business Media.
- Ferreira, F. & Peragine, V., 2015. Equality of Opportunity: Theory and Evidence. Policy Research Working Paper. World Bank Group.
- Ferrer, M., 1992. Los sistemas urbanos. Síntesis s.a.
- Forkenbrock, D.J. & Foster, N.S., 1990. Economic Benefits of a Corridor Highway Investment. Transportation Research, (24).
- Foth, N., Manaugh, K. & El-Geneidy, A.M., 2013. Towards equitable transit: examining transit accessibility and social need in Toronto, Canada 1996-2006. Journal of Transport Geography, 29, pp.1-10.
- Galindo, E.L.S., 1963. Consideraciones sobre el óptimo de Pareto. El Trimestre Económico, 30, 119(3), pp.351-58.
- Gannon, C.A. & Liu, Z., 1997. Poverty and Transport. Discussion Paper. World Bank (Transport Division).
- Givoni, M., 2006. Development and impact of the modern high-speed train: A review. Transport reviews, 26 (5), 593-611.
- Glaeser, E.L. & Kohlhase, J.E., 2004. Cities, Regions and the Decline of Transport Costs. Papers in Regional Science, 83(1), pp.197-228.
- Groom, B., Hepburn, C., Koundouri, P. & Pearce, D., 2005. Declining Discount Rates: The long and the Short of it. Environmental & Resource Economics, 32, pp.445-93.
- Harberger, A.C., 1971. Three basic postulates for applied welfare economics: an interpretive essay. Journal of Economic Literature, 9(3), pp.785-97.
- Harberger, A., 1978. On the Use of Distributional Weights in Social Cost-Benefit Analysis. Journal of Political Economy, 86 (2) [Part 2: Research in Taxation], pp.87-120.
- Harris, E. & Kende-Robb, C., 2008. Integrating Macroeconomic Policies and Social Objectives: Choosing the Right Policy Mix for Poverty Reduction. In A.A.D.&.A.d. Haan, ed. Inclusive States: Social Policy and Structural Inequalities. Washington DC: New Frontiers of Social Policy. pp.97-120.
- Henderson, N. & Bateman, I., 1995. Empirical and public choice evidence for hyperbolic social discount rates and the implications for intergenerational discounting. Environmental and Resource Economics, 5(4), pp.413-23.
- Henisz, W.J. & Zelner, B.A., 2006. Interest groups, veto points, and electricity infrastructure deployment. International Organization, 60(1), pp.263-86.
- Hensher, D., Truong, P., Mulley, C. & Ellison, R., 2012. Assessing the wider economy impacts of transport infrastructure investment with an illustrative application to the North-West Rail Link project in Sydney, Australia. Journal of Transport Geography, 24, pp.292-305.
- Hess, D.B. & Almeida, T.M., 2007. Impact of proximity to light rail rapid transit on station-area property values in Buffalo, New York. Urban Studies, 44(5-6), pp.1041-68.
- Higgins, C. & Kanaroglou, P., 2018. Rapid transit, transit-oriented development, and the contextual sensitivity of land value uplift in Toronto. Urban Studies, 55(10), pp.2197-225.
- Hine, J., 2008. Transport and Social Justice. Malden: Blackwell Publishing.
- Hine, J.P. & Grieco, M.S., 2003. Scatters and clusters in time and space: Implication for delivering integrated and inclusive transport. Transport Policy, 10(4), pp.299-306.
- HM Treasury, 2003. The Green Book: appraisal and evaluation in central government: Treasury guidance. Stationery Office.

- Holtz-Eakin, D. & Lovely, M.E., 1996. Scale Economies, Returns to Variety, and the Productivity of Public Infastructure. Regional Science and Urban Economics, 26(2), pp.105-23.
- INFRAS, 2014. Update of the Handbook on External Costs of Transport. Report for the European Commission.
- ISR, 2017. The Panel Study of Income Dynamics (PSID). A national study of socioeconomics and health over lifetimes and across generations. PSID Main Interview User Manual: Release 2017. Institute for Social Research, University of Michigan.
- ITF, 2017. Quantifying the socioeconomic benefits of transport. International Transport Forum; Roundtable Reports, nº160. OECD Publishing.
- ITF, 2018. Strategic Investment Packages. International Transport Forum; Case-Specific Policy analysis. OECD Publishing.
- Jim, M.R. & Love, P., 2011. Infrastructure procurement: learning from private ^ public partnership experiences 'down under'. Environment and Planning C: Government and Policy, 29, pp.363-78.
- Johansson-Stenman, O., 2005. Distributional Weights in Cost-Benefit Analysis. Should We Forgot about Them? Land Economics, 81(3), pp.337-52.
- Johnstone, N. & Serret, Y., 2006. The Distributional Effects of Environmental Policy. OECD Publishing.
- Kain, J.F., 1968. Housing Segregation, Employment, and Metropolitan Decentralization. Journal of Economics, 82(2), pp.175-97.
- Karen, L., 2006. Providing transport for social inclusion within a framework for environmental justice in the UK. 40(10), pp.801-09.
- Khraibani, R., De Palma, A., Picard, N. & & Kaysi, I., 2016. A new evaluation and decision making framework investigating the elimination-by-aspects model in the context of transportation projects' investment choices. Transport Policy, 48, pp.67-81.
- Krugman, P., 1991. Increasing Returns and Economic Geography. The Journal of Political Economy, 99(3), pp.483-99.
- Layard, R., 1980. On the use of distributional weights in social cost-benefit analysis. Journal of Political Economy, 88(5), pp.1041-49.
- Leleur, S., Salling, K.B. & Jensen, A.V., 2007. Documentation and Validation of the TGB Evaluation model in Greenland. Technical Report prepared for the Home Rule Authorities in Greenland, Centre for Traffic and Transport, Technical University of Denmark.
- Litman, T., 1996. Using Road Pricing Revenue: Economic Efficiency and Equity Considerations. Transportation Research Record: Journal of the Transportation Research Board, 1558(1), pp.24-28.
- Litman, T., 2011. Evaluating accessibility for transportation planning. Victoria, BC: Victoria Transport Policy Institute.
- Lowe, J., 2008. Intergenerational Wealth Transfers and Social Discounting: Supplementary Green Book Guidance. London: HM Treasury.
- Mackie, P.J., Graham, D. & Laird, J., 2011. The direct and wider impacts of transport projects: a review. In Handbook of Transport Economics. Edward Elgar Publishing.
- Mackie, P.J., Jara-Dıaz, S. & Fowkes, A.S., 2001. The value of travel time savings in evaluation. Transportation Research Part E: Logistics and Transportation Review, 37(2), 91-106.
- Manaugh, K. & El-Geneidy, A., 2012. Who benefits from new transportation infrastructure? Using accessibility measures to evaluate social equity in transit provision. In Geurs, K., Krizek, K.R. & Reggiana, A. Accessibility and Transport Planning: Challenges for Europe and North America. London: Edward Elgar. pp.211-27.
- Martens, K., 2006. Basic Transport Planning and Principles of Social Justice. Berkely Planning Journal, 19(1), pp.1-17.
- Martens, K., Golub, B. & Robinson, G., 2012. A justice-theoretic approach to the distribution of transportation benefits: implications for transportation planning practice in the United States. Transportation Research Part A: Policy and Practice, 46, pp.684-95.
- McCrae, M. & Aiken, M., 2000. Accounting for Infrastructure Service Delivery by Government: Generational Issues. Financial Accountability and Management, 16(3), pp.267-87.
- Meunier, D., Quinet, A. & Quinet, E., 2013. Project apparisal and long term strategic vision. In 41st European Transport Conference. Frankfurt, 2013. Elsevier.
- Mooney, G. & Jan, S., 1997. Vertical equity: weighting outcomes? or establishing procedures?. Health Policy, 39(1), pp.79-87.

- Mueller, N. et al., 2016. Urban and transport planning related exposures and mortality: a health impact assessment for citie. Environmental health perspectives, 125(1), pp.89-96.
- Mulley, C., 2014. Accessibility and residential land value uplift: Identifying spatial variations in the accessibility impacts of a bus transitway. Urban Studies, 51(8), pp.1707-24.
- Myung-Jin, J., 2012. Redistributive effects of bus rapid transit (BRT) on development patterns and property values in Seoul, Korea. Transport Policy, 19, pp.85-92.
- Narváez, M., Fernández, G. & Senior, A., 2008. El desarrollo local sobre la base de la asociatividad empresarial: una propuesta estratégica. Opción, Revista de Ciencias Humanas y Sociales, (57), pp.74-92.
- Nixon, H.; Holian, M.; Niles, J.; Pogodzinski, J.M. 2018. Measuring the Economic Impact of High-Speed Rail Construction for California and the Central Valley Region. College of Business of San José State University & Mineta Transportation Institute.
- OECD, 2002. Impact of transport infrastructure investment on regional development. OECD Publications.
- Oosterhaven, J. & Elhorst, J.P., 2004. Indirect Economic Benefits of Transport Infrastructure Investments. In World Conference on Transport Research Society. Lyon, 2004.
- Oosterhaven, J. & Knaap, T., 2003. Spatial economic impacts of transport infrastructure investments. In A. Pearman, P.M.&.J.N. Transport Projects, Programmes and Policies: Evaluation Needs and Capabilities. Ashgate, Aldershot. pp.87-1.
- Padilla, E., 2001. Equidad intergeneracional y sostenibilidad. Las generaciones futuras en la evaluación de políticas y proyectos. Tesis Doctoral. Barcelona: Universitat Autonoma de Barcelona.
- Parry, I.W., Mylonas, V. & Vernon, N., 2018. Policies for implementing the Paris Agreement: an assessment for G20 countries. Unpublished manuscript, International Monetary Fund. Washington, DC.
- Pearce, D.W. & Nash, C.A., 1981. The Social Appraisal of Projeccts. A Text in Cost-Benefit Analysis. Londres: Macmillan.
- Penyalver, D. & Turró, M., 2017. Assessing the Fairness of a Project Financing Formula on Successive Generations. International Journal of Transport Economics, 44(1), pp.153-176.
- Penyalver, D., Turró, M. & Zavala-Rojas, D., 2018. Intergenerational Perception of the Utility of Major Transport Projects. Research in Transportation Economics (70), pp.97-111.
- Pilcher, J., 1994. Mannheim's sociology of generations: an undervalued legacy. British Journal of Sociology, 45(3).
- Priemus, H. & van Wee, B., 2017. Megaproject Decision Making and Management; Ethical and Political Issues. The Oxford Handbook of Megaproject Management.
- Puga, D., 2002. European regional policies in light of recent location theories. Journal of Economic Geography, 2, pp.373-406.
- Röller, L.H. & Waverman, L., 2001. Telecommunications Infrastructure and Economic Development: A Simultaneous Approach. American Economic Review, 100(2), pp.909-23.
- Rasch, E.D. & Köhne, M., 2017. Practices and imaginations of energy justice in transition. A case study of the Noordoostpolder, the Netherlands. Energy Policy, 107, pp.607-614.
- Raux, C., Souche, S. & Mercier, A., 2006. De l'équité à l'acceptabilité des politiques de transport: que peut le calcul économique? CNRS, Université Lyon 2, ENTPE.
- Rawls, J., 1972. A Theory of Justice. Cambridge, Mass.: Harvard University Press, p.475
- Rawls, J.,1974. Some Reasons for the Maximin Criterion. The American Economic Review, Vol. 64, No. 2, Papers and Proceedings of theEighty-sixth Annual Meeting of the American Economic Association pp. 141-146.
- RCPCH, 2016. Every breath we take: The lifelong impact of air pollution, report of a working party. Project Report. Royal College of Physicians/Royal College of Paediatrics and Child Health.
- Redding, S.J. & Turner, M., 2014. Transportation costs and the spatial organisation of economic activity. (processed), Princeton.
- Rietveld, P., 1989. Infrastructure and regional development. The Annals of Regional Science, 23(4), pp.255-74.
- Román, C., 2001. Aprendiendo a innovar. El papel del capital social. Instituto de Desarrollo Regional, (18).
- Scanlon, T.M., 1998. What we owe to each other. Cambridge MA. Harvard University Press.
- Stiglitz, J.E., 1997. The Role of Government in Economic Development. In Annual Work Bank Conference on Developments Economics, 1996. Washington D.C., 1997. M. Bruno & B. Pleskovic.

- Stough, R., Vickerman, R., Button, K. & Nijkamp, P., 2002. Transport Infrastructure Cheltenham. In Classics in Transport Analysis. Northampton, MA, USA: Elgar Reference Collection.
- Teixeira, A.C., 2006. Transport policies in light of the new economic geography: the Portuguese experience. Regional Science and Urban Economics, 36(4), pp.450-66.
- Thomopoulos, N., Grant-Muller, S. & Tight, M.R., 2009. Incorporating equity considerations in transport infrastructure evaluation: Current practice and a proposed methodology. Evaluation and Program Planning, 32, pp.351-59.
- Thompson, J., 2003. Intergenerational Equity; Issues of principle in the allocation of social resources between this generation and the next. Research Paper 7, 2002-2003. Commonwealth of Australia, Department of the Parliamentary Library.
- Townsend, P., Phillimore, P. & Beattie, A., 1988. Health and deprivation: inequality and the North. Routledge
- Trannoy, A., 2011. Equity Dimensions of Transport Policy. In Handbook of Transport Economics. Edward Elgar Publishing.
- Turró, M., 1979. El valor de los ahorros de tiempo en los viajes por carretera. PhD dissertation on the value of travel time. Universitat Politécnica de Catalunya (UPC, Barcelona).
- Turró, M., 1999. Going trans-European. Planning and financing transport networks for Europe. Elsevier Science, Oxford, 1999. (http://goingtens.turro.cat/).
- Turró, M., 2004. RAILPAG. Railway Project Appraisal Guidelines. European Commission and European Investment Bank. Available online at: http://www.eib.org/projects/publications/railpag-railway-project-appraisal-guidelines.htm
- Turró, M., 2015. Sobre la toma de decisiones en las inversiones en transporte. Revista de Obras Públicas, 162(3566), pp.27-32.
- Turró, M. & Penyalver, D., 2019. Hunting white elephants on the road. A practical procedure to detect harmful projects of transport infrastructure. Research in Transportation Economics (pending publication).
- Ulied, A., 1995. Definición de una medida de accesibilidad regional. Tesis Doctoral. Universitat Politécnica de Catalunya. Barcelona.
- Ulltveit-Moe, K.H., 2007. Regional policy design: An analysis of relocation, efficiency and equity. European Economic Review, 51.
- United Nations, 1987. An Overview by the World Commission on Environment and Development. Our Common Future: Report of the WorldCommission on Environment and Development.
- van Dijk, M., 2016. European Urban Knowledge Network (EUKN): Socio-Economic Segregation in EU Capital Cities. Available online at: http://www.eukn.eu/news/detail/eukn-urban-review-socio-economic-segregation-in-eu-capital-cities/
- van Wee, B., 2012. How suitable is CBA for the ex-ante evaluation of transport projects and policies? A discussion from the perspective of ethics. Transport Policy, 19, pp.1-7.
- Venales, A., 2015. Incorporating wider economic impacts within cost-benefit appraisal. International Transport Forum (Paris).
- Vickerman, R., 2004. Private Financing of Transport Infrastructure: Some UK Experience.
- Vickerman, R., 2017. Wider Impact of Megaprojects. In Flyvberg, B. The Oxford handbook of megaproject management. Oxford University Press. p.289.
- Viegas, J.M., 2001. Making urban road pricing acceptable and effectivie: searching for quality and equity in urban mobility. Transport Policy, 8, pp.289-94.
- Vieira, E., 2008. Capital humano como factor de convergencia: Análisis econométrico de la Euoregión Galicia-Norte de Portugal (19955-2002). Tesis Doctoral. Universidad de Santiago de Compostela.
- Vining, A.R. & Boardman, A.E., 2008. Public-Private Partnerships. Eight Rules for Governments. Public Works Management and Policy, 13(2), pp.149-61.
- Vinning, A.R. & Weimber, D.L., 2015. The challenges of fractionalized property rights in public-private hybrid organizations: The good, the bad, and the ugly. Regulation & Governance, 10(2).
- Wade-Benzoni, K.A., Hernandez, M., Medvec, V. & Messick, D., 2008. In fairness to future generations: The role of egocentrism, uncertainty, power, and stewardship in judgments of intergenerational allocations. Journal of Experimental Social Psychology, 44(2), pp.233-45.

- Weisbrod, G., 2015. Estimating Wider Economic Impacts in Transport Project Prioritisation Using Ex-Post Analysis. Draft Discussion Paper prepared for the Roundtable on Quantifying the Socio - Economic Benefits of Transport. Paris: The International Transport Forum.
- Williamson, J.B. & Rhodes, A., 2011. A critical assessment of generational accounting and its contribution to the generational equity debate. International Journal of Ageing and Later Life, 6(1), pp.33-57.
- Winston, C., 2006. Government Failure versus Market Failure. AEI-Brookings Joint Centre for Regulatory Studies. Available online at: https://www.brookings.edu/wp-content/ uploads/2016/06/20061003.pdf
- World Bank, 2013. Inclusion Matters: The Foundation for Shared Prosperity. Washington, DC: New Frontiers of Social Policy.
- WHO, 2010. Environmental and health risks: A review of the influence and effects of social inequalities. World Health Organisation, Regional Office for Europe.

6. APPENDIX A: LITERATURE REVIEW CONCERNING THE REDISTRIBUTION EFFECTS OF TRANSPORT INFRASTRUCTURE INVESTMENTS

The efficiency benefits stemming from major transport infrastructure investments are unevenly distributed among the project's stakeholders. Besides, they entail a diversity of redistributive effects of territorial, social and/or environmental nature that are indeed relevant for decision makers. Academics and practitioners have made attempts to identify and forecast them over the years on the basis that the project's redistributive effects may be used to reduce disparities among particular population groups, territories or generations. The use of investments as a policy instrument indicates that the redistribution of benefits can be substantial. A quick search using Google Scholar confirms the importance of redistribution effects in relation to transport infrastructure (cf. Table II-A1).

Table II-A1. Results from keyword research using Google Scholar (period 1900-2018)

Key term (*)	Refining words (**)	Number of studies(***)
redistribution	transport infrastructure	42,600
redistribution	transport infrastructure investment	24,900
spatial **redistribution**	transport infrastructure investment	1,320
social **redistribution**	transport infrastructure	1,260
social **redistribution**	transport infrastructure investment	1,200
spatial **redistribution**	transport infrastructure	1,870
redistribution effects	transport infrastructure	1,290
redistribution effects	transport infrastructure investment	1,110
territorial **redistribution**	transport infrastructure	424
territorial **redistribution**	transport infrastructure investment	335
intergenerational **redistribution**	transport infrastructure	181
environmental **redistribution**	transport infrastructure	6
environmental **redistribution**	transport infrastructure investment	2
classification **redistribution** effects	---	0
redistributive effects	transport infrastructure	2,900
redistributive effects	transport infrastructure investment	2,640
intergenerational **redistributive effects**	transport infrastructure	12
spatial **redistributive effects**	transport infrastructure	9
territorial **redistributive effects**	transport infrastructure	4
social **redistributive effects**	transport infrastructure	2
environmental **redistributive effects**	transport infrastructure	0
classification **redistributive effects**	---	0

(*) Words with quotation marks around in the search

(**) Words without quotation marks around in the search

(***) Journal articles, conference papers, chapters in books, etc.

Source: Author

The table shows the outputs obtained during the search using a mandatory word and refining words. They indicate the index-linked documents of Google Scholar in which the key term was found at least one time. The outputs provided by Google Scholar do not offer information, however, on whether the main term of the search is actually "key" in the study, as would be the hypothetical case if an author would have attempted to identify/classify (for the first time) the different redistribution effects of infrastructure investment. Should this had been the case, the term/s "redistribution/redistributive effects" would had appeared explicitly as "keyword".

On the other hand, it is worthwhile noting that if the key term used in the search encompasses not only the word "redistribution/redistributive effects" but also the word "classification/territorial/social/environmental/intergenerational" the number of studies found in Google Scholar fall to a few of them or there are no matches (cf. Table II-A1).

The results obtained from the use of the former key terms with some of the main academic databases (WOS, CCC, DIIDW, KJD, MEDLINE, RSCI, SCIELO, etc.) also confirm that no author (excluded the authors of this paper) has included the mandatory words shown in Table A-1 as "keyword" in any disseminated work. This would confirm the hypothesis that no other author has ever made attempt to classify the redistributive effects of transport infrastructure. This hypothesis has been also confirmed through the review of both the pieces of literature related to transport economics shown in Section 5 of this paper (bibliographic references) and other pieces found through Google Scholar using "redistributive effects" as key term plus "transport infrastructure" as refining words (cf. Table II-A2).

Table II-A2. Main pieces of academic literature dealing with the redistribution effects of transport infrastructure

Document of reference	number of cites
Botham, R.W. (1980). The regional development effects of road investment. Transportation Planning and Technology, 6(2), 97-108.	60
Howe, J. (1981). Income Distribution and Employment Programme: The Impact of Rural Roads on Poverty Alleviation: a Review of the Literature (Vol. 106). International Labour Office.	29
Cervero, R. (1981). Efficiency and equity impacts of current transit fare policies (No. 799).	34
Starrs, M., & Perrins, C. (1989). The markets for public transport: the poor and the transport disadvantaged. Transport Reviews, 9(1), 59-74.	20
Rietveld, P. (1989). Infrastructure and regional development. The Annals of Regional Science, 23(4), 255-274.	229
Lemelin, C. (1992). Short-term redistributive effects of public financing of university education in Quebec. Canadian Public Policy/Analyse de Politiques, 176-188.	19
Broome, J., 1992. Counting the costs of global warming. Cambridge: White Horse Press.	573
Quinet, E. (1994). The social costs of transport: evaluation and links with internalisation policies. Internalising the social costs of transport, 31-76.	94
Bénabou, R. (1994). Human capital, inequality, and growth: A local perspective. European Economic Review, 38(3-4), pp.817-26.	164
Rietveld, P. (1994). Spatial economic impacts of transport infrastructure supply. Transportation Research Part A: Policy and Practice, 28(4), 329-341.	139
De la Fuente, A. & Vives, X. (1995). Infrastructure and education as instruments of regional policy: evidence from Spain. Economic policy, 10(20), 11-51.	441
Verhoef, E., Nijkamp, P., & Rietveld, P. (1995). Second-best regulation of road transport externalities. Journal of transport economics and policy, 147-167.	122
Arrow, K.J., Cline, W.R., Maler, K.G., Munasinghe, M., Squitieri, R., Stiglitz, J.E., 1996. Intertemporal equity, discounting and economic efficiency. Cambridge University Press, (pp. 125-44)	667
Head, K. & Ries, J. (1996). Inter-city competition for foreign investment: static and dynamic effects of China's incentive areas. Journal of Urban Economics, 40(1), 38-60.	539
Vickerman, R. (1997). High-speed rail in Europe: experience and issues for future development. The annals of regional science, 31(1), 21-38.	385
Doménech, R., Maudes, A., & Varela, J. (2000). Fiscal flows in Europe: the redistributive effects of the EU budget. Review of World Economics, 136(4), 631-656.	45
Banister, D. & Berechman, Y. (2001). Transport investment and the promotion of economic growth. Journal of transport geography, 9(3), 209-218.	542
De la Fuente, A., & Doménech, R. (2001). The redistributive effects of the EU budget: an analysis and proposal for reform. JCMS: Journal of Common Market Studies, 39(2), 307-330.	95
Démurger, S. (2001). Infrastructure development and economic growth: an explanation for regional disparities in China?. Journal of Comparative economics, 29(1), 95-117.	1083
Preston, J. (2001). Integrating transport with socio-economic activity–a research agenda for the new millennium. Journal of Transport Geography, 9(1), 13-24.	101
Feitelson, E. (2002). Introducing environmental equity dimensions into the sustainable transport discourse: issues and pitfalls. Transportation Research Part D: Transport and Environment, 7(2), 99-118.	105
Asensio, J., Matas, A., & Raymond, J.L. (2003). Redistributive effects of subsidies to urban public transport in Spain. Transport Reviews, 23(4), 433-452.	37

(Table continues next page…)

Table II-A2. Main pieces of academic literature dealing with the redistributive effects of transport infrastructure

Paper reference	cites
Asensio, J., Matas, A. & Raymond, J.L. (2003). Petrol expenditure and redistributive effects of its taxation in Spain. Transportation Research Part A: Policy and Practice, 37(1), 49-69.	41
Banister, D., & Berechman, J. (2003). Transport investment and economic development. Routledge.	722
Calderón, C. & Servén, L. (2004). The effects of infrastructure development on growth and income distribution. The World Bank.	1000
Coombs, G. & Dollery, B. (2004). The Ageing of Australia: Fiscal Sustainability, Intergenerational Equity and Inter-temporal Fiscal Balance. Australian Journal of Social Issues, 39(4), 459-470.	12
Geurs, K.T. & Van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: review and research directions. Journal of Transport geography, 12(2), 127-140.	1496
Holl, A. (2004). Manufacturing location and impacts of road transport infrastructure: empirical evidence from Spain. Regional Science and Urban Economics, 34(3), 341-363.	317
Matas, A. (2004). Demand and revenue implications of an integrated public transport policy: the case of Madrid. Transport Reviews, 24(2), 195-217.	97
Rodríguez-Pose, A. & Fratesi, U. (2004). Between development and social policies: the impact of European Structural Funds in Objective 1 regions. Regional Studies, 38(1), 97-113.	573
Castells, A. & Solé-Ollé, A. (2005). The regional allocation of infrastructure investment: The role of equity, efficiency and political factors. European Economic Review, 49(5), 1165-1205.	208
Musterd, S. (2005). Social and ethnic segregation in Europe: levels, causes, and effects. Journal of Urban Affairs, 27(3), pp.331-48.	536
Kemmerling, A. & Stephan, A. (2008). The politico-economic determinants and productivity effects of regional transport investment in Europe. EIB papers, 13(2), 36-60.	33
López, E., Gutiérrez, J. & Gómez, G. (2008). Measuring regional cohesion effects of large-scale transport infrastructure investments: an accessibility approach. European Planning Studies, 16(2), 277-301.	173
Martínez-Vázquez, J. (2008). The Impact of Budgets on the Poor: Tax and Expenditure Benefit Incidence Analysis. In Public Finance for Poverty Reduction. Blanca Moreno-Dodson & Quentin Wodon. The Word Bank.	49
Geurs, K. T., Boon, W. & Van Wee, B. (2009). Social impacts of transport: literature review and the state of the practice of transport appraisal in the Netherlands and the United Kingdom. Transport reviews, 29(1), 69-90.	143
Cervero, R. & Kang, C.D. (2011). Bus rapid transit impacts on land uses and land values in Seoul, Korea. Transport Policy, 18(1), 102-116.	251
Lakshmanan, T.R. (2011). The broader economic consequences of transport infrastructure investments. Journal of Transport Geography, 19(1), 1-12.	217
Cassiers, T. & Kesteloot, C. (2012). Socio-spatial inequalities and social cohesion in European cities. Urban Studies, 49(9), pp.1909-1924.	115
Jun, M.J. (2012). Redistributive effects of bus rapid transit (BRT) on development patterns and property values in Seoul, Korea. Transport Policy, 19(1), 85-92.	42
Martens, K., Golub, A. & Robinson, G. (2012). A justice-theoretic approach to the distribution of transportation benefits: Implications for transportation planning practice in the United States. Transportation Research Part A: Policy and Practice, 46(4), 684-695.	132
Rietveld, P. & Bruinsma, F. (2012). Is transport infrastructure effective?: Transport infrastructure and accessibility: impacts on the space economy. Springer Science & Business Media.	395
Sterner, T. (2012). Distributional effects of taxing transport fuel. Energy Policy, 41, 75-83.	93
Viguié, V. & Hallegatte, S. (2012). Trade-offs and synergies in urban climate policies. Nature Climate Change, 2(5), 334.	105
Foth, N., Manaugh, K. & El-Geneidy, A.M. (2013). Towards equitable transit: examining transit accessibility and social need in Toronto, Canada 1996-2006. Journal of Transport Geography, 29, pp.1-10.	135
Foxley, A., Aninat, E. & Arellano, J.P. (2013). Redistributive effects of government programmes: The Chilean case. Elsevier.	66
Li, Y. & DaCosta, M.N. (2013). Transportation and income inequality in China: 1978–2007. Transportation Research Part A: Policy and Practice, 55, 56-71.	19
Berri, A., Lyk-Jensen, S.V., Mulalic, I. & Zachariadis, T. (2014). Household transport consumption inequalities and redistributive effects of taxes: a repeated cross-sectional evaluation for France, Denmark and Cyprus. Transport Policy, 36, 206-216.	10
Condeço-Melhorado, A., Tillema, T., de Jong, T. & Koopal, R. (2014). Distributive effects of new highway infrastructure in the Netherlands: The role of network effects and spatial spillovers. Journal of Transport Geography 34, pp. 96-105	8
Geroliminis, N., Zheng, N. & Ampountolas, K. (2014). A three-dimensional macroscopic fundamental diagram for mixed bi-modal urban networks. Transportation Research Part C: Emerging Technologies 42, pp. 168-181	40
Condeço-Melhorado, A., Zofío, J.L. & Christidis, P. (2017). Drivers of changes in Spanish accessibility for the 1960–2010 period. European Transport Research Review, 9(2), 19.	2
Knaap, T. & Oosterhaven, J. (2017). Spatial economic impacts of transport infrastructure investments. In Transport Projects, Programmes and Policies (pp. 87-105). Routledge.	102

Source: Google Scholar

In short, it can be argued that a proper identification/classification of the redistributive effects stemming from major investments in transport infrastructure has never been attempted, according to both the analysis performed through the main academic databases and a thorough review of the literature on transport project appraisal. Thus, the identification and classification of the differential impacts of major transport infrastructure projects (redistribution effects), including territorial, social, environmental and intergenerational impacts may be considered as a new and genuine contribution of this doctoral thesis.

7. APPENDIX B: CASE STUDY WITH S/E MATRIX

This appendix presents the case study of a shadow-toll motorway to illustrate the use of the Stakeholders/Effects Matrix to analyse the redistributive effects among project-linked stakeholders.

The project concerns the construction of 30 km of a dual 2-lane motorway. The GPI is a regional government that will develop the project through a long-term concession based on shadow-toll payments by means of a DBFMO[41] contract. The concessionaire is expected to receive a minimum concession fee yearly, determined from agreed demand forecasts, with the aim of ensuring that the project is financially sustainable for the private sector. Besides, if demand overcomes a certain threshold, the GPI will endure additional payments to compensate the concessionaire for the additional maintenance costs. Investment in the infrastructure to be covered by the concessionaire is estimated at €92 million exclusive of VAT. Most of the works (€59 million) will be carried out by the concessionaire' main contractor. The construction works are expected to take place over a period of 3 years; the concession period covers this period plus 23 years afterwards. At the end of the concession (26 years), the project is assumed to have a 45% residual value. Both routine maintenance costs and renewals costs due to periodical heavy maintenance works are assumed to be the responsibility of the concessionaire.

In the socioeconomic analysis, the adopted project economic cost is €85 million. The difference between the financial and the economic cost (€7 million) is due to the use of shadow prices for labour. The project's benefits for users are mostly related to savings in terms of both travel time and automobile operating costs (fuel consumption, tyre wear, etc.) and to safety improvements. The project also entails positive impacts for users of the existing roads. The effects on non-users are environmental (noise, air pollution, greenhouse gases emissions and others), and other related to land values, economic development, etc.

According to a classical Cost-Benefit Analysis, the investment is economically sound and the economic rate of return is quite high (ERR=13.8%) and robust (cf. Table II-B1). Travel time values and operating costs appear as important variables on the socioeconomic profitability of the project. The results of the calculations also reveal a satisfactory financial rate of return (FRR=9.6%) for the private investors.

[41] A DBFMO contract implies for the private partner to design, build, finance, maintain and operate the infrastructure. Finally, at the end of the concession period, the concessionaire delivers the assets to the conceding GPI ensuring optimal conditions of use, but without the right to any compensation.

Table II-B1. Economic Evaluation of shadow-toll motorway (example)

Project: Shadow-toll mortorway (DBFMO) –example–	NPV	Rate	Year	1	2	3	4	5	10	15	20	25	26
		5,0%											
INVESTMENT & MAINTENANCE; million €													
Project Investment Costs													
Cost to the GPI (Regional government)	108 M€			9,1	73,3	38,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Investment: project economic cost	85 M€			7,0	59,0	29,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Project financial cost (cost to concessionaire)	92 M€			7,7	62,4	32,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Main contractor cost (cost to concesionnaire)	59 M€			6,9	29,8	29,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Project cost to main contractor	44 M€			5,2	22,4	22,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Residual value (45% end of the period)	13 M€			0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	46,2
Taxes (VAT at 17.5%)	16 M€			1,4	10,9	5,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Total investment: financial cost	95 M€			9,1	73,3	38,3	0,0	0,0	0,0	0,0	0,0	0,0	-46,2
Total investment: economic cost	72 M€			7,0	59,0	29,0	0,0	0,0	0,0	0,0	0,0	0,0	-46,2
VAT revenue to National government	16 M€			1,4	10,9	5,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Operation & Maintenance Costs													
O&M cost to concessionaire	27 M€			0,0	0,0	0,0	1,4	1,4	2,7	3,2	2,4	1,4	1,4
Routine maintenance	14 M€			0,0	0,0	0,0	1,2	1,2	1,2	1,2	1,2	1,2	1,2
Renewals to concessionaire (heavy maintenance)	10 M€			0,0	0,0	0,0	0,0	0,0	1,1	1,5	0,9	0,0	0,0
Taxes (VAT at 17.5%)	4 M€			0,0	0,0	0,0	0,2	0,2	0,4	0,5	0,4	0,2	0,2
Total economic costs	96 M€			7,0	59,0	29,0	1,2	1,2	2,3	2,7	2,0	1,2	-45,0
Total financial costs	123 M€			9,1	73,3	38,3	1,4	1,4	2,7	3,2	2,4	1,4	-44,8
BENEFITS; million €													
Users Benefits													
Socioeconomic benefits for users	210 M€			0,0	0,0	0,0	0,0	12,8	16,3	20,3	24,6	30,2	31,5
Travel Time Savings	148 M€			0,0	0,0	0,0	0,0	9,0	11,2	14,2	17,6	22,0	23,0
Operating Cost Savings	49 M€			0,0	0,0	0,0	0,0	3,0	4,0	4,8	5,5	6,5	6,7
Safety benefits	13 M€			0,0	0,0	0,0	0,0	0,8	1,1	1,3	1,5	1,7	1,8
External Effects													
Socioeconomic benefits for users and non users	20 M€			0,0	0,0	0,0	1,8	1,8	1,8	1,7	1,6	1,4	1,4
Variation in land value	24 M€			0,0	0,0	0,0	2,1	2,1	2,1	2,1	2,1	2,1	2,1
Variation in noise emissions	-2 M€			0,0	0,0	0,0	-0,1	-0,1	-0,1	-0,2	-0,2	-0,3	-0,3
Variation in air pollution	-1 M€			0,0	0,0	0,0	-0,1	-0,1	-0,1	-0,1	-0,2	-0,2	-0,2
Variation in CO2 emissions	-1 M€			0,0	0,0	0,0	-0,1	-0,1	-0,1	-0,1	-0,1	-0,2	-0,2
Total soecioeconomic benefits	230 M€			0,0	0,0	0,0	1,8	14,6	18,1	22,0	26,2	31,7	33,0
Benefits – Costs (economic)	134 M€			-7,0	-59,0	-29,0	0,7	13,5	15,8	19,3	24,2	30,5	78,0
		ERR= 13,8%											
Shadow tolls from the GPI (Regional government)													
Revenues to concessionaire	200 M€			0,0	0,0	0,0	10,6	11,1	14,2	18,1	23,1	29,5	30,9
Concession fee	170 M€			0,0	0,0	0,0	9,0	9,5	12,1	15,4	19,6	25,1	26,3
Taxes (VAT at 17.5%) borne by the GPI	30 M€			0,0	0,0	0,0	1,6	1,7	2,1	2,7	3,4	4,4	4,6
Overall financial profitability of the project	77 M€			-9,1	-73,3	-38,3	9,2	9,7	11,5	14,9	20,7	28,1	75,8
		FRR= 9,6%											

Source: Author

7.1. RESULTS OF STAKEHOLDER ANALYSIS

Table II-B2 shows a very simplified S/E Matrix[42]. The values in the rows are relevant to show who benefits the most from the project and who pays. In this case the Regional government is taking most of the burden whilst the National government is obtaining some net gain through tax revenues. Private investors (concessionaire) and construction companies appear as major beneficiaries of the project. Moreover, the table shows how some of the economic costs and benefits can only be partially reflected in financial cash flows, as it is the case of the shadow prices on labour.

[42] In a real case it would be particularly important to analyse the effects on the existing road network and on the areas presently suffering from congestion. The S/E matrices may eventually become quite extensive. In general, the cells contain an economic and a financial component, unless the market and the economic value can be assumed to be the same.

Table II-B2. S/E Matrix of shadow-toll motorway (example)

Project: Shadow-toll mortorway (DBFMO) –example–									
		STAKEHOLDERS							
EFFECTS		Users	Wider beneficiaries	Concessionaire	Main contractor	Regional government (GPI)	National government	ECONOMIC VALUE (Benefits – Costs)
USERS BENEFITS	Travel Time Savings	148 M€						148 M€
	Operating Cost Savings	49 M€						49 M€
	Safety benefits	13 M€						13 M€
EXTERNAL EFFECTS	Variation in land value		24 M€					24 M€
	Variation in noise emissions		-2 M€					-2 M€
	Variation in air pollution		-1 M€					-1 M€
	Variation in CO2 emissions		-1 M€					-1 M€
ASSETS	Infrastructure: **financial**			111 M€	59 M€	-170 M€		0 M€
	economic			-48 M€	-44 M€	7 M€		-85 M€
	Infrastructure Maintenance			-23 M€				-23 M€
	Residual Value					13 M€		13 M€
	Taxes (VAT)					-30 M€	30 M€	0 M€
FINANCIAL PROFITABILITY		210 M€	20 M€	40 M€	15 M€	-180 M€	30 M€	134 M€

Discount Rate: 5,0%

Source: Author

As can be easily observed, users are the main beneficiaries of the project (ENPV=210 M€). Their benefits (travel time savings, operating costs and safety benefits) are high enough for the GPI to justify the project from the socioeconomic point of view. Actually, should the analysis exclude the external effects of the project in the CBA, the project ERR would still be high (12.5%). On the other hand the project has other beneficiaries, which are the property owners of land and/or real state within the area of influence of the project that will benefit from the increase of land value stemming from the project (ENPV=24 M€). It is worth noting here that such increase of land value is indeed an indirect effect of the project as it is expected that the motorway of the example will boost economic development locally in the long run (not included here; the increase in land value may cover this "additional" externality, which is also partially included through the induced traffic component in traffic forecasts). Besides, the project entails very modest environmental impacts of local, regional and global scope that, in monetary terms, mean a negative ENPV of some 4 M€, which could be separated in the S/E Matrix if necessary.

SECTION III. ASSESSING THE FAIRNESS OF A PROJECT FINANCING FORMULA ON SUCCESSIVE GENERATIONS

Penyalver, D. & Turró, M., 2017

Abstract

Major transport projects are appraised mostly through cost-benefit analysis. In practice, though, decision-making takes into account many other aspects that are more or less political. When properly defined, they may be introduced in the decision process through multi-criteria analysis. Most important among these aspects are redistributive effects, which are, typically, associated to territorial, social and environmental considerations. There are, however, some important redistribution effects that have never been properly analysed and quantified until now. They are related to the evolution, throughout the projects' lifespan, of the costs and benefits of the project affecting successive (overlapped) generations, and of the financing structure adopted, which determines who the final payers will be: either users, through tolls or tariffs for the use of the project, and/or taxpayers. Relating the actual payment for the investment to the net benefits occurring to the users and citizens in general for each generation, it is possible to ascertain if there is a balanced intergenerational distribution of burdens and benefits over the whole project lifecycle.

The *"Intergenerational Redistributive Effects Model" (IREM)*, a model based on a survey-based definition of the "annual generation", includes an ad-hoc analytical procedure for the establishment of indicators of these effects allowing their comparison among different projects. Such indicators could provide a valuable input into the decision making process and, in particular, in the adoption of a financing structure that represents an adequate share of the actual investment expenditure among those who will benefit from the project.

1. INTRODUCTION

Public administrations need to promote investments in transport infrastructure to provide an adequate welfare level to the population. These investments must be profitable in terms of resources, taking into account society as a whole along the whole lifespan of the asset. Most of these resources, both costs and benefits, can be monetised allowing the measurement of the efficiency of the project through cost-benefit analysis (CBA). Some objectives having a weight in decision making by elected officials are not, however, properly included in the efficiency measure, as they cannot be appropriately converted into money. Among these objectives, regional development, which pursues the economic and social convergence of less developed regions, is often the focus of multi-year projects that require large amounts of financial resources until implemented. These territorial redistributive effects are not, however, the only ones having an impact on decision making. Social, environmental and purely political objectives are more or less influential in the decision process and have been the subject of academic research. However, while certain redistributive aspects, such as the impact on regional development, have been the target of many theoretical and experimental analyses, the redistributive effects of major projects affecting different generations of citizen, although indirectly present in many decisions processes, have not been addressed until now.

In most countries it is the taxpayer who pays for the construction, operation and maintenance of transport infrastructure (directly from the public budget or through public companies, such as railway infrastructure managers), although users are providing funds to the government through specific taxes, such as fuel taxes. In some countries, and for certain sections (tunnels, bridges) almost everywhere, users also pay tolls or fees for infrastructure use. Independently of the contribution of users, the funding of the investment, which often involves loans, can imply very different disbursements over time. The financing structure adopted for a new infrastructure can thus show strong variations and seriously affect the distribution of the benefits and particularly the burdens of the project. Without going deeply into the issue of how the transport sector is taxed, what is obvious is that the financing model adopted may have important differential effects on the various actors involved in the project and that these effects may vary considerably over time. It is also easy to understand that their impact on the society "of each moment" affected by the project could be quite different. The aim of this paper is to show the possibility of incorporating in the socioeconomic analysis of major investments a component indicating the effects of the financing formula of the project on the various overlapped generations of users and taxpayers affected.

The effects of the financing formula of a specific project for the public sector are obviously embedded in the global macroeconomic context. Typically, the yearly budget[1] of governments is mostly composed by tax income plus some public debt. So, it could be argued that the effects of the total public debt are those really relevant for future (genealogical) generations[2]. The implications of the marginal increase in public debt brought about by major projects are not, however, our concern here. New major projects are funded, traditionally, by means of some budgetary contributions and ad-hoc financial commitments that, in general, will only concern users and (mostly) taxpayers during the project's lifespan. Accordingly, what we aim at analysing here is the relation between the socioeconomic effects of new investments, measured in term of resources, and the concomitant financial flows –and the equity implications– linked to

[1] Governments' yearly budget typically involves the forecast of the annual public expenditure, financial commitments from former investments and financial resources for scheduled new projects. Public debt in a year "i" will be compound by Treasury debt (bonds) and other specific financial liabilities from former investments (loans) funded via private banks, IFIs or project bonds.

[2] In fact, taxpayers have to cover, in any case, the legacy of the cumulated Treasury debt generated in the past by loans to old projects.

these projects on the “annual generations” of users and taxpayers during the life cycle of the project. What is important within the decision-making process for a major project is to generate awareness of all the implications that are relevant for society and, if possible, to provide indicators allowing their proper assessment.

The *“Intergenerational Redistributive Effects Model”* (onwards, IREM) described below is a powerful tool that facilitates the analysis of whether, over time, the beneficiaries of investment (users and society of "every moment") contribute in a balance manner, through pay per use and/or taxes, to obtaining the benefits generated by the project or if there is a dissociation between these two flows. In synthesis, whether the time distribution of the net benefits and the financing contributions entail a significant redistribution between the overlapped generations affected by the project. With this objective a fourth-pronged index that measures the *"intergenerational impacts"* of investment is proposed, to inform the evaluator of the project, and finally to decision-makers, about the risk that the financing formula may induce significant intergenerational effects.

2. MEASURING INTERGENERATIONAL EFFECTS

The concept of “generation” (and, by extent, the concept of “intergenerational”) is used by most scientific papers with a genealogical meaning without a clear definition of its timespan. This lack of definition is evident both in key macroeconomic studies related to the analysis of consumption and of savings on economic growth (Ramsey, 1928; Solow, 1956; Samuelson, 1958; Phelps, 1961; Weiss, 1980; Romer, 1986; Blanchard & Fischer, 1989; Romer, 1990; Romer & Chow, 1996; Kotlikoff & Burns, 2005; Gahvari & Micheletto, 2014). A clear definition is also absent in microeconomic studies, which aim to obtain the social discount rate[3], and in studies that aim to assess the implicit distribution in the CBA of the intergenerational preferences of society (Scaborough & Bennet, 2008; Scaborough, 2011). Despite this, certain microeconomic studies even have tried to differentiate between the intra-generational and the inter-generational effects of the projects (Eckstein, 1958; Marglin, 1963; Angelsen, 1991; Moore et al., 2004; Fernández-Baca, 2011). For example, Moore et al. (2004) argue that, in a period of 50 years, two generations (our generation and that of our children) are typically overlapped, and therefore, considering a longer duration would unduly incorporate more distant future generations. For this reason they consider that, taking into account the period of time required for most public infrastructure projects to be fully depreciated, the reasonable length for a genealogical generation is 50 years. This seems clearly excessive for a discussion about intergenerational equity. Although it is evident that some identification exists both with ancestors and with distant descendants, the concept of generation has always focused on individuals who share some specific experiences and who are jointly valuing their contribution to society, and this requires much shorter time spans.

From the microeconomic perspective the question is, however, whether the discount economic flows really reflects how people perceives the way that collective investments affect their intertemporal welfare, and if it generates awareness on the decision-makers on how the financing formula adopted by the Government Promoting the Investment (onwards, GPI) to pay for the

[3] The theory of discounted utility is the most widely used framework for analysing economic decisions that have consequences in multiple time periods (intertemporal choices), such as infrastructure investment. When studying the mechanisms of decision-making it is clear that future outcomes are considered less important than immediate (present) outcomes (Soman et al., 2005). On the other hand, the most accepted discounted model assumes that intertemporal welfare function is a weighted sum of the flow of current and future utility and, in turn, that utility can be referred to as consumption or income (Arrow & Kurz, 1970; Arrow et al., 1995; Laibson, 2003; Gollier, 2011).

investment affects their constituencies. The relation between the socioeconomic effects of a project, measured in term of resources, and the concomitant financial flows –and their fairness implications– has not been properly specified and analysed until now. The CBA focuses on offering the (static) socioeconomic net value of the investment at the moment of assessing the project. It does so through the use of discount rate associated to the time preference of consumption of society (social value) or reflects the profitability that could be obtained from the economic resources spent in the project in the best alternative investment (social cost). Both values could be quite different (Feldstein, 1964; Arrow & Kurz, 1970; Angelsen, 1991; Laibson, 2003; Souto, 2003; Arrow et al., 2004; Moore et al., 2004; Fernández-Baca, 2011; Gollier, 2011), i.e. it is not possible to speak of a single appropriate discount rate[4] (Stiglitz, 2013). In short, the discounting mechanism is not suitable to reflect the impact that the financing structure of a project will have on the beneficiaries and taxpayers from different generations.

The IREM has been developed as a tool to respond to this issue and facilitate the analysis of whether there is a balanced distribution over time of the relation between what the beneficiaries of an investment (users and society of "each moment") receive and their contribution through pay per use and/or taxes. The "intergenerational" term used in this model is a concept that enables taking into account the dynamic of the effects on people (users and taxpayers "of each moment") of different project financing structures over time. The model shows the variability of the relation between the financial and socioeconomic effects of an investment in transport infrastructure over the years within the limits of the project's lifespan. Therefore, this concept is strictly linked to the individuals yearly-affected by the project and, in addition, it nuances their traditional genealogical attributes according to other aspects representing how useful is a transport project for society belonging to any "annual generation".

A basic question for the analysis of intergenerational phenomena is, of course, to determine what is the most appropriate method to group the affected individuals so the model properly reflects the differential effects over identifiable and separate groups that are affected by the project over the years. This has been done through the definition of an "annual generation" (see point 4), which involves the critical assumption about the timespan covered by it and also how the individuals of years around the central year of the generation are included. These parameters can only be estimated through adequate surveys indicating the sensitivity of society to the effects of a major transport infrastructure.

3. CHARACTERISTIC PROFILES OF A TRANSPORT INVESTMENT PROJECT

Decision-makers typically use the CBA method to assess the efficiency of investments in terms of resources for society as a whole. Once socioeconomic costs and benefits have been quantified and monetized throughout the life cycle of the project (usually by annual periods), they both are compared each other in order to calculate the net benefits (benefits minus costs). The benefits for users may be evident, but those obtained by the community directly concerned by the investment or the positive externalities affecting society in general (global environmental effects, macroeconomic impacts, etc.) are more difficult to identify and value. Concerning costs, in addition to the resources consumed during construction, operation and maintenance of a new transport infrastructure, it is necessary to include both environmental (increased noise, pollution, etc.) and other possible social costs. It must be stressed here that neither the yearly net benefits nor the outcome of the CBA are affected by the transfers of resources between users and

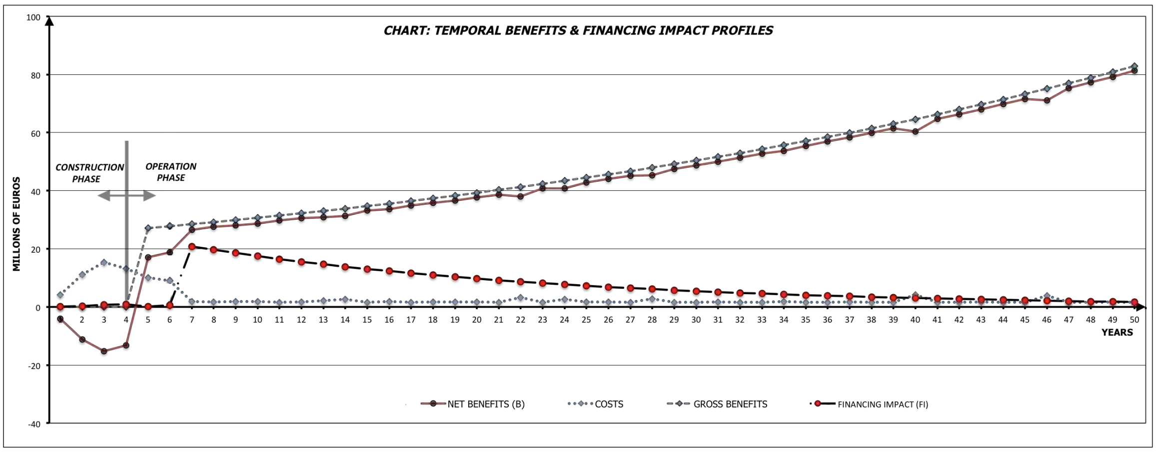
[4] In fact, even though some international organisations recommend about the discount rates to apply in CBA for different types of investments, most public authorities follow their own policy regarding the estimation and use of the discount rate (HM Treasury, 2003; Evans & Sezer, 2004; Meunier et al., 2013).

operators or between them and the government (fees, taxes, etc.), which are, on the other hand, critical for the financial structuring of the project.

The financial implications of the project can be derived from the cash flows, which specify all expenses and incomes that affect the various stakeholders in the project. To ensure the overall financial sustainability of the project it is necessary that the cumulative income forecast for each agent, among which should be included subsidies and transfers from other actors (such as, for example, bank loans), always exceeds the cumulative costs (including the return of credits) they have to face. A precise estimation of the costs of construction, maintenance and operation over time of the transport infrastructure, on the one hand, and of the expected revenues from its exploitation and from other possible contributions of public budgets on the other, will allow us to establish the external financial needs of the project, which will usually be covered by loans. For each financing option, i.e. each combination of revenues, grants and loans, there will be a different distribution of the financing burden over time and between users and taxpayers. A critical factor in such a distribution is the budget contributions of the different governments involved in the project. European subsidies supporting “convergence" regions, for instance, have had an important impact on the financial structure of many transport infrastructure projects across Europe.

Comparing the time profile of the net financial “cash flows corresponding to payments” (revenue payments minus outlays) and the time profile of the “flows of socioeconomic net benefits” over the project life cycle allows us to identify how the financing burden is shared each year between users and taxpayers and what is the gap between the amounts paid and the net benefits from the project (cf. Figure III-1). This comparison gives us information about the redistributive effects that occur due to the financing formula of the project and how they affect different generations of users and taxpayers.

Figure III-1. Characteristic socioeconomic and financial time-profiles (obtained from a particular project)



Source: Author

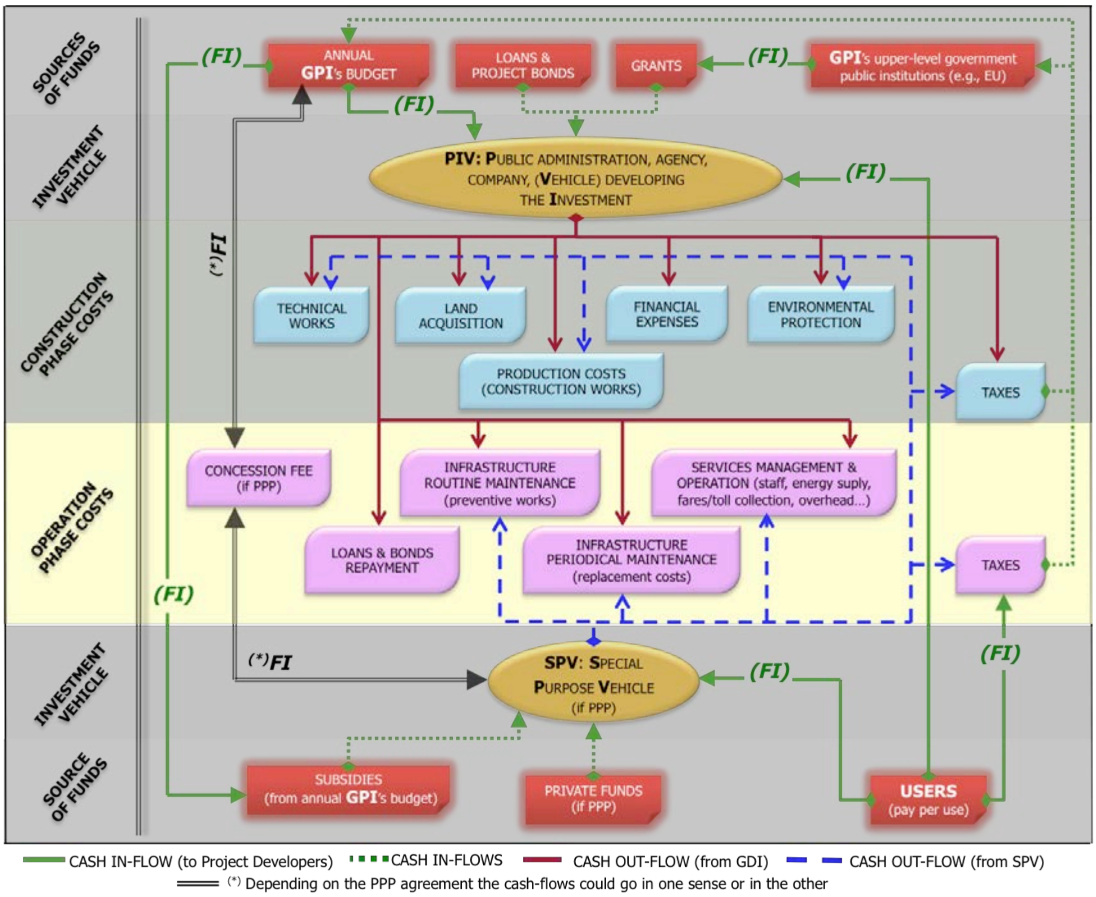
From the time profile of the *net socioeconomic benefits (B_i)* and the time profile of the *financing impact (FI_i)* it is possible to obtain, for each year, the difference between them *(D_i)* across the project life cycle. The IREM model compares the cash flows from the financial analysis with the flow of socioeconomic benefits, thus their values must be in constant terms.

Equation III-1. Difference between net benefits value and financing impact in year “i”

$$D_i = B_i - FI_i$$

It must be stressed that *FI* is determined by the payment schedule and that payments are not necessarily made in the same year when the expenses originated. The profile shows, thus, the resources provided by each funding source (through the investment vehicle chosen by GPI). This includes tolls, fees, etc. levied on the various users and the funds devoted to the project coming from the public budgets either to reimburse the loans (principal and interests) assigned to the project or to pay for the investment, operation and maintenance costs not covered by the former loans (cf. Figure III-2). Private sector funds mobilised by the project, either as equity or loans, are not considered as such in the *FI:* since they may be assumed to have alternative options in the market with similar financial effects on society, they may be considered having a neutral effect in terms of intergenerational impact. What is clearly affecting the *FI* are the payments made by users and GPIs to the Project Developer[5] (e.g. when there are shadow tolls) to the private partner in a PPP, throughout the operation phase of the project, that he will use to repay the loans, to recover the equity and for eventual profits. Financial flows not directly attributable to the project shall not be included.

Figure III-2. Key sources of financing and links of cash in/out-flows to obtain the financing impact (FI)



Source: Author

[5] The investment vehicle chosen by the GPI to develop the project may be totally public, being managed by the Administration itself, a public Agency or Company, named here as a Public Vehicle of Investment (PIV), or totally or partially private (Special Purpose Vehicle of Investment or SPV) when carried out through a PPP (including a pure concession).

Figure III-2 shows how the investment vehicle chosen by the GPI to develop the project determines what payments have to be considered as a direct financing expenditure from the perspective of the users and taxpayers eventually paying for the investment, which is the GPI point of view. When the GPI finances a project directly or through a PIV without recourse to real tolls or other users payments, the *FI* for taxpayers will be determined by the cash out-flows in the annual budgets needed to pay for both construction and operation costs. Loans, project bonds and other possible financing instruments will only affect the GPI's annual budget at the time when principal and interests will be paid.

When the GPI carries out a project through a PPP, it is possible that the GPI receives money (a "concession fee") from the concessionaire but often users are not expected to pay over the years for the totality of costs. In this case, the GPI will have to cover the required compensation (a "negative concession fee") to the SPV through shadow tolls, availability payments, etc. or establish some kind of subsidy. The cash out-flows needed for these payments originate in the corresponding annual budgets and are thus supported by the taxpayers[6].

4. DEFINING THE GAP FOR EACH ANNUAL GENERATION

Even if the difference between the net benefits and the financial contributions of users and non-users of the project in each given year shows strong differences between two correlative years (for instance, before and after completion of the grace period of a loan), the simple difference does not provide a clear-enough indicator on how different generations will be affected. As already mentioned, the first step to get a suitable indicator of intergenerational redistributive effects is to properly define the concept of "annual generation" (AG_i) pivoting around year, *i*, of the life cycle of the project.

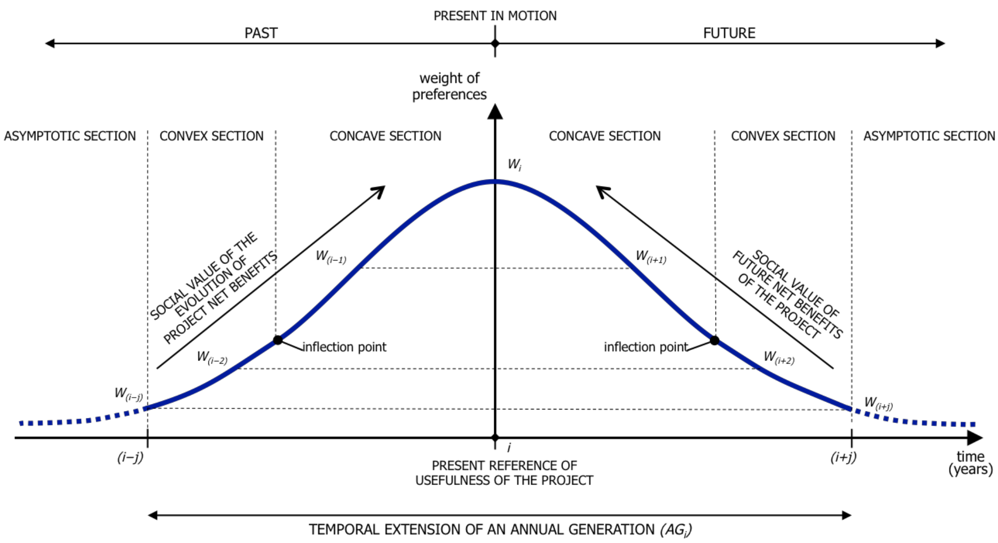
Considering any year "i" in the life cycle of the project as the "central year" or pivotal moment associated to an annual generation "AG_i", from this mid position, the individuals (both users and taxpayers) who live in this year will fully obtain all the net benefits and bear the financing legacy of the investment (payments related to the project funding) of that year, but only a part of the effects occurring in preceding or following years. Most of the *"i"* year individuals have already been affected in the past by the project and will probably survive to be affected in future years. They will be, however, less numerous and bound by more uncertainties as they find themselves farthest from the pivotal year. It is also reasonable to assume, for the analysis of the intergenerational effects between overlapped generations, a similar principle to the one used in CBA, which uses discount rates. People of the central year of a future generation would prefer "real[7]" benefits in that year over uncertain ones, which means, that they will give less weight to costs and benefits that will occur either before or after the year in question. On both counts it is logical to apply some mitigation (attenuation of the year's weight) and to do it in a more or less symmetrical way. This should not be the case, however, for generations living during the first years of the project, as its effects only start with payments and/or the commissioning of the transport infrastructure.

[6] In both cases (PIV or SPV), any taxes (VAT or other) paid by users or the GPI, even if recovered by a public administration, will be considered as a financing expenditure within the year. This is arguable, but the discussion about taxes in CBA deserves a research that falls outside the present remit.

[7] "Real" refers here to benefits accrued with certainty in the year

So, once defined the annual generation's timespan, it is possible to establish its profile, assuming a symmetrical and continuous form of percentage weights[8] *(w_j)* decreasing towards the more distant years. The (theoretical) graphic function resulting is the *weighting curve* shown in Figure III-3).

Figure III-3. Weighting curve for each annual generation "AG_i"



Source: Author

Having defined the profile of the intergenerational effects, it is possible to calculate a *gap* for each annual generation as the sum of the outcomes resulting of multiplying each *"D_i"* by its corresponding weighting coefficient[9] "w_j" for every year, *j,* included in the AG_i (cf. Equation III-2).

Equation III-2. GAP for an annual generation centred in year "i"

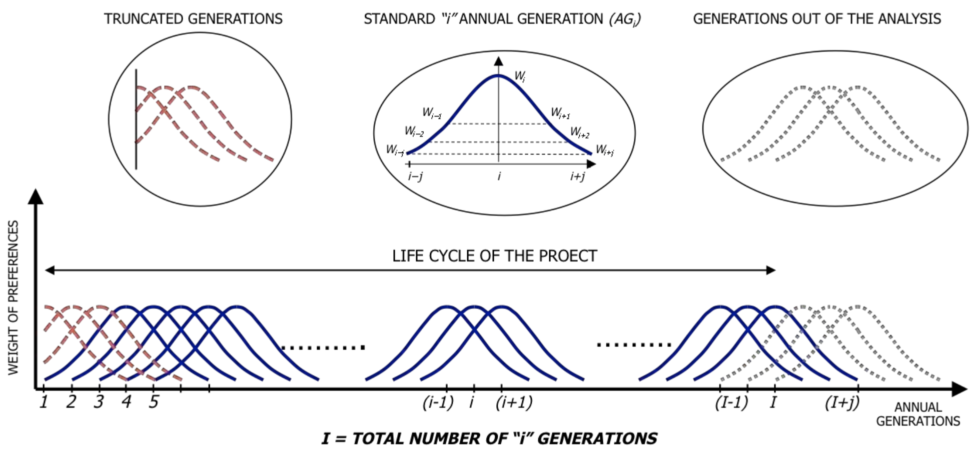
$$GAP_i = \sum_{i-j}^{i+j} D_j \cdot w_j \; ; \; \sum_{i-j}^{i+j} w_j = 1$$

The *"GAP_i"* provides a profile over the life cycle of the project that shows whether its financing formula leads to similar situations between generations or if important redistributive effects exist among them. But, as already mentioned, and as shown in Figure III-4, it is not logical to include the differences between costs and benefits occurring in years previous to the initiation of the project. In these years previous to the lifespan of the project there are no resources (generated or used) to consider. Therefore, the GAP_i of the annual generations before the first "complete" one (i.e. when $j=1$ of this generation coincides with the first year of works), or "initial generations", have to be calculated using a truncated weighting profile. This profile should be based on people's identification with the nearest past with regards to the project. It would seem that the perception of a project could be strongly related to the construction period and its impact on employment and the short-term generation of economic activity. The profile could thus be dependant on the economic performance of the region at the time, but an average reasonable pattern could be established for all projects, as acceptable variations would have a relatively minor impact on intergenerational indicators.

[8] Percentage weights correspond to people's perception/preferences about the project's utility either before or after the 'central year' of an annual generation.

[9] Theoretical weighting coefficients have been used for defining the shape of the curve (Figure III-3).

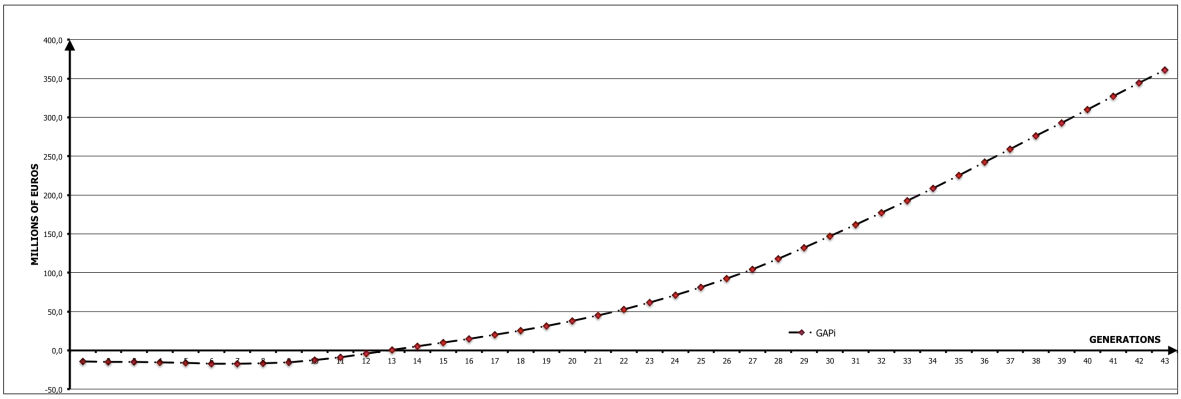
Figure III-4. Generational assessment of the inter-annual differences between costs and benefits



Source: Author

At the other end of the project cycle, the problem may be solved simply by considering that the generational analysis will end *"j"* years later than the period of analysis adopted in the CBA (*"I"* years). For the last standard-annual generations *($AG_{i=I}$),* the calculation will end *"j"* years after the analysis period adopted. We can argue that the transport infrastructure will still be in operation after year *"i=I"* and the net benefits occurring afterwards can be extrapolated without distorting the intergenerational analysis.

Figure III-5. Time Profile of Generational Gaps of the project (example)



Source: Author

From the gap of each *"annual generation"* it can be drawn up the *"Time Profile of Generational Gaps"* of the project (cf. Figure III-5), which is useful to determine whether the financing formula of a project implies substantial differences in the distribution of the gaps over its lifecycle and to easily check if certain generations are paying more than the net benefits they receive *($GAP_i<0$).* As negative gaps are perceived more strongly than positive ones (with the size of these positive effects being relatively irrelevant), a simple quantified indicator of the existence of a potential problem for decision makers seems sufficient for inclusion in the intergenerational analysis. The *"Generational Unfairness Indicator" (GUI),* which gives the percentage of the number of generations with negative gaps *(NEGAP)* over the total annual generations *(N)* considered (cf. Equation III-3).

Equation III-3. Calculation of "Generational Unfairness Indicator" of the project

$$GUI = \left(\frac{NEGAP}{N}\right) \cdot 100$$

5. THE MODEL OF THE INTERGENERATIONAL REDISTRIBUTIVE EFFECTS

The IREM model proposes standardized indicators as a common baseline to compare the intergenerational effects of different projects and, in particular, the different options available to finance them. In order to do so, it is necessary to calculate, first, the average value of the different generational gaps obtained along the project lifespan ($\overline{GAP}$) and, next, the *intergenerational gap (GAP_{intg-i})* for each year according to Equations III-4 and III-5.

Equation III-4. Calculation of the mean gap of the "GAP_i" series

$$\overline{GAP} = \frac{\sum_{i=1}^{N} GAP_i}{N}$$

Equation III-5. Calculation of the "Intergenerational GAP" for each annual generation

$$GAP_{intg-i} = GAP_i - \overline{GAP}$$

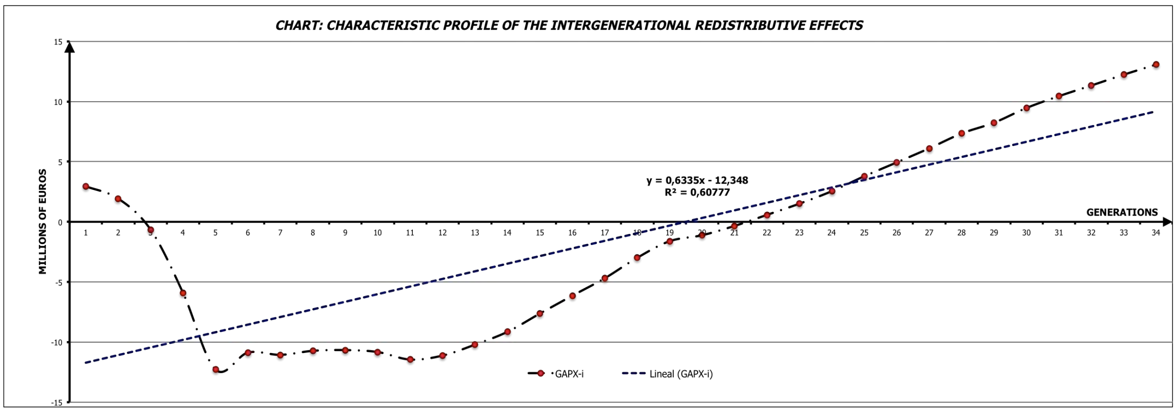
The variations over the life cycle of GAP_{intg-i} indicate whether some annual generations are more or less affected by the financial model than others. However, as the impacts on society of future gaps are mitigated by the wealth growth of its members, which is usually measured through the GDP (gross domestic product), the above calculations have to be modified to take into account the reduced value of the gaps between expected net socioeconomic benefits and payments for generations[10] to come. It is done as shown in Equation III-6, discounting from the GAP_{intg-i} series the *long-term annual growth of GDP/c* following an exponential pattern similar to the social discount rate. The modified intergenerational GAP for each generation is represented as GAP_{X-i}.

Equation III-6. Calculation of "modified intergenerational GAP" for each annual generation

$$GAP_{X-i} = \frac{GAP_{intg-i}}{(1 + TC_{GDP/c})^{(i-1)}}$$

Figure III-6 shows the typical linear profiles of a given financing formula. The slope of the best-fit line (positive or negative) indicates whether, globally, the proposed financing structure will tend to (relatively) benefit or harm future generations. The slope of the regression gives the strength of the gap in favour of future generations.

Figure III-6. Characteristic time-profile of the intergenerational redistributive effects (example)



Source: Author

[10] By considering that it is established a weighting coefficient to calculate the *GAP* for each annual generation *"i"*, it could be argued that reducing now the value of the GAP_{intg-i} by means of the *GDP/c* implies a double discounting. However, the weights for each year *"j"* within each generation defines, together with its time span, the relevance for society of the project's effects. It is not related at all to reducing future *GAP's* values because their transcendence will be mitigated by the society's wealth growth.

The bigger the angle of the slope the highest will be the benefits for them. On the other hand, the distance of each *"GAP_{X-i}"* with regards to the geometrical line resulting of the linear regression of the whole *"intergenerational gap series"* allows us to determine whether a specific generation is more positively (or negatively) affected than others.

The linear correlation coefficient of the gap series *"r" ($-1\leq r \leq 1$),* which determines the relationship between the two variables involved in a bidimensional distribution will provide an indicator of the variability with regards to a specific regression line, which reflects a situation where all generations would be identically affected (independently of the sign of future effects).

Equation III-7. Linear correlation coefficient

$$r = \frac{\sigma_{xy}}{\sigma_x \cdot \sigma_y}; \quad -1 \leq r \leq 1$$

In the formula, σ_{xy} is the arithmetic mean of the deviations products for each variable from its mean (covariance); σ_x is the square root of the variance of the gap series (typical standard deviation); and σ_y is the typical standard deviation of the time distribution of generations of the projects *(i=1, 2, 3… I)*. When the trend of the linear profile of *"GAP_{X-i}"* series is strong *($r\approx 1$ or $r\approx -1$),* the redistributive effects due to the variability among generations are small and the sharing of financing cost and socioeconomic benefits among the different generations is homogeneous, although they could generally be in favour or not of future citizens. However, when the correlation is weak *($r\approx 0$)*, it means that there is a big dispersion of *GAP* values and some generations will benefit clearly from the project whilst others will bear its financing burden.

To facilitate the understanding of the redistributive intergenerational effects, the IREM model defines an dimensionless indicator, the *"Intergenerational Redistributive Effects Sharing Index"* or *IRESI,* to reflect the overall intensity of the intergenerational redistributive effects independently of the trend, which could be as much increasing as decreasing (which is not very common but theoretically possible).

Equation III-8. Intergenerational Redistributive Effects Sharing Index (IRESI)

$$IRESI = 1 - R^2_{GAP\,[X]}\,; \quad IRESI \in [0,1]$$

In the formula, r^2, the coefficient of determination of the GAP_{X-i} series, is represented by $R^2_{GAP\,[X]}$ represents. A high value of the *IRESI* indicates that there are strong divergences among generations regarding (and irrespective of) the general trend of the project, which could favour closer or more distant "societies". *$IRESI\approx 0$* values indicate that the intergenerational redistribution effects are consistent and therefore, in this case, the only characteristic to consider is the trend (the slope of the regression line).

When the intergenerational redistributive effects that the financing formula entails are important, it will be necessary to assess separately the *IRESI* associated to each agent involved in the project, particularly users and taxpayers. This will require calculating independently the *IRESI* for both agents, to analyse the importance of the possible differences and the reasons for them.

In sum, the *"Intergenerational Redistributive Effects Model" (IREM)* is a microeconomic model that offers three key parameters (outputs) to describe intergenerational redistributive effects:

- *GUI:* Indicates to what extent a project will entail *"generational unfairness"*.
- Trend: Indicates us whether present or future generations will be favoured.
- Slope[11]: Tangent of the regression line, giving the strength of the trend.
- *IRESI*: Indicates whether particular generations will end up being greatly benefited/ harmed due to the financing model.

This information can be used to assess the intergenerational redistributive effects of the different formulae that a GPI could choose for funding a project but also to compare intergenerational redistributive effects between different projects.

6. ANALYSIS OF THE IREM MODEL. A PRACTICAL APPLICATION

The IREM model has been used for a specific case for which reliable data were available. The aim of the exercise was, on one hand, to detect the practical difficulties of its implementation and, on the other hand, to get a first impression of the potential effects on the indicators of some theoretical hypotheses (length of annual generations, weighting curves of the population, etc.) that have been adopted on a pure conceptual basis. The current research being carried out with the European Investment Bank (EIB) sponsorship[12] and, in particular, its fieldwork component should allow answering some of the IREM model questions still open, especially whose related with the sensitivity of society to the effects of a transport infrastructure project (that is, the weighting curve) and with the annual generation length.

In the baseline scenario, the extension of a standard annual generation has been set at seven years and the weighting curve of the population has been defined, in accordance with it (cf. Table III-1). In the case study an average yearly growth rate of GDP per capita equal to 1.7% has been considered in the long term (BdE, 2012) based on the Central Bank of Spain forecast. The values of the net benefits series and the yearly financing expenditure beyond 30 years, for which data is not available since the CBA of the project does not take them into account, have been extrapolated[13].

Table III-1. Weighting of society's yearly consumption preferences

GENERATION	WEIGHTS (w_j)						
	year 1	year 2	year 3	year 4	year 5	year 6	year 7
Standard (7 years)	0.060	0.085	0.180	0.350	0.180	0.085	0.060
Truncated (6 years)	—	0.090	0.192	0.372	0.192	0.090	0.064
Truncated (5 years)	—	—	0.210	0.410	0.210	0.100	0.070
Truncated (4 years)	—	—	—	0.517	0.267	0.126	0.090

Source: Author

[11] In order to compare different projects "trend & slope" *(T&S)* should be shown in grades; $-100g \leq T\&S \leq +100g$.

[12] Through the STAREBEI programme 2015/16 of the EIB Institute the EIB finances and provides technical support and information to this research project, which is aimed at producing a doctoral thesis. More detailed information is now available in the STAREBEI report (Penyalver & Turró, 2016).

[13] Extrapolation of the yearly net socioeconomic benefits series beyond the last year of the stated project economic-lifecycle can be done taking into account just the period of years needed to cover the calculations of the model for the last generation in the timespan considered. For the yearly financing expenditure series, on the other hand, it has to be taken into account the amortisation periods in the funding components and whether there exist (or not) financing burdens to bear after the lifecycle considered in the CBA.

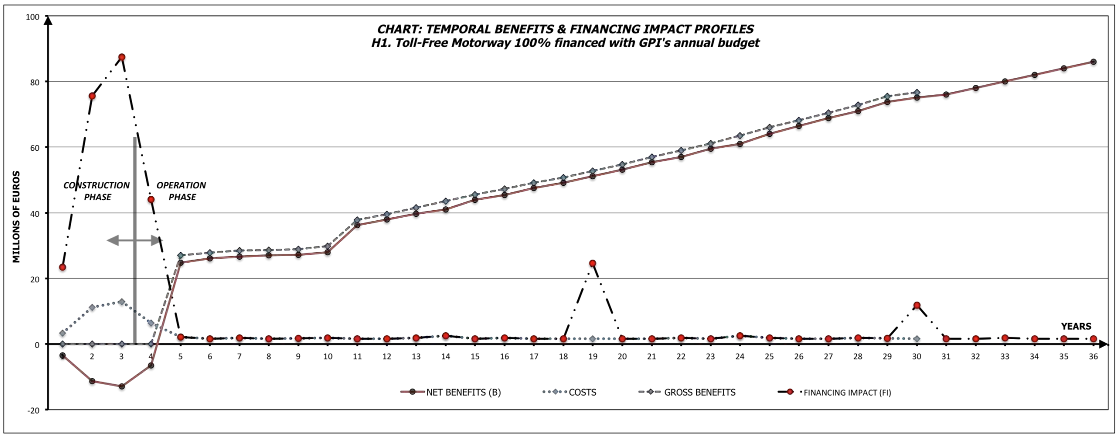
The case analysed corresponds to the Almanzora motorway, stretch Baza to Purchena, promoted in Spain by the Government of Andalusia (GPI)[14]. Since this stretch is part of a toll-free motorway (A-334) no "pay per use" system has been considered. The project lifecycle has been set at 30 years (4 years construction phase plus an operation phase of 26 years). The average yearly long-term inflation rate used in the financial analysis is 2.25%. On the other hand, environmental effects occurring during construction and throughout the operation phase have not been taken into account in the CBA. The net increase (or decrease) of regional economic activity due to new accessibility conditions has not been computed either. Yearly inflows of socioeconomic benefits (in constant terms) have been obtained for all scenarios as a result of the monetization of the lower operation cost of vehicles, reduced travel times and fewer accidents that the new transport infrastructure entails versus the option of not making any accessibility improvement (current situation).

The assessment conducted by the GPI has been performed as part of the process to tender the construction, maintenance and operation of the motorway under a concession to a private operator. The data provided have allowed the analysis of the potential effects of the financing formula proposed by GPI (H4) but also for three alternative conventional formulae:

- Scenario H1. Characteristic profile with budgetary funding
- Scenario H2. Characteristic profile with conventional bank-funding
- Scenario H3. Characteristic profile with partial bullet-loan
- Scenario H4. Characteristic profile with private concession

In scenario H1, GPI finances exclusively with its budget the main investment and the project's costs of maintenance and operation. Any grant or contribution (e.g. from the CE) is not taken into account, so the profile of the financial impact that will bear GPI is consistent with the financial outflows of the project, including the rehabilitation investments foreseen on years 19 and 30 (cf. Figure III-7).

Figure III-7. Characteristic socioeconomic and financial time-profiles of the project (H1.budgetary funding)



Source: Author

Based on the net economic benefits flows *(B)* and the financial contributions *(FI)* of the project the *GAP* for each generation has been obtained (cf. Table III-2).

[14] Relevant information has been obtained from the Junta de Andalucía official website; *"Estudio de viabiidad económico-financiera para la construcción, conservación y explotación";* contract dossier n. 1-AA-2900-2.0-0.0-EG.

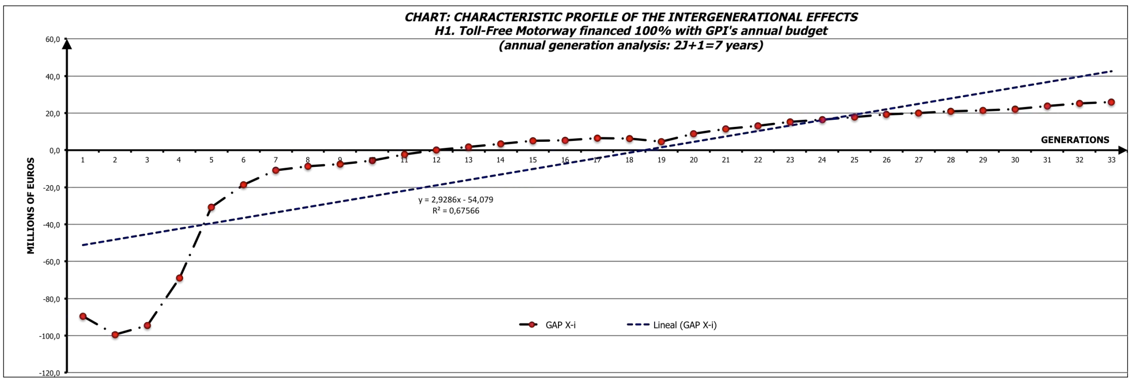
Table III-2. Analysis of the intergenerational redistributive effects (H1)

AG_i	GAP_i	$GAP_{intg\text{-}i}$	$GAP_{X\text{-}i}$
1	-54.3	-89.6	-89.6
2	-65.8	-101.1	-99.4
3	-62.5	-97.8	-94.6
4	-37.1	-72.4	-68.8
5	2.4	-32.9	-30.8
6	14.9	-20.4	-18.7
7	23.4	-11.9	-10.7
8	25.6	-9.7	-8.6
9	26.8	-8.5	-7.4
10	28.9	-6.4	-5.5
11	32.6	-2.7	-2.3
12	35.3	0.0	0.0
13	37.4	2.1	1.7
14	39.5	4.2	3.4
15	41.7	6.4	5.1
16	42.3	7.0	5.4
17	43.7	8.4	6.4
18	43.5	8.2	6.2
19	41.5	6.2	4.6
20	47.4	12.1	8.8
21	51.5	16.2	11.6
22	54.1	18.8	13.2
23	57.6	22.3	15.4
24	59.5	24.2	16.4
25	62.1	26.8	17.8
26	64.6	29.3	19.2
27	66.3	31.0	20.0
28	68.3	33.0	20.9
29	69.5	34.2	21.3
30	71.5	36.2	22.2
31	74.9	39.6	23.9
32	77.7	42.4	25.2
33	79.9	44.6	26.0

Source: Author

By analysing the *"GAP_i"* series it is possible to observe that the financing formula involves differential impacts. In this scenario they are particularly negative for generations 1 to 4, which means that the population paying for the main investment expenses will not be sufficiently compensated by the net socioeconomic benefits generated by the project.

Figure III-8. Time-profile of the intergenerational redistributive effects (H1)

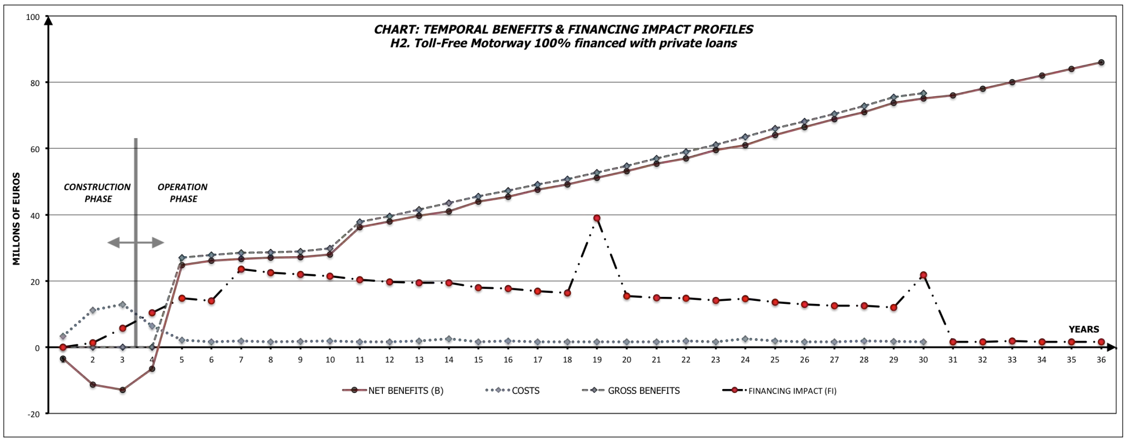


Source: Author

To analyse the redistributive effects from an intergenerational perspective, we build the *time profile of the intergenerational gap* (cf. Figure III-8), which shows a $T\&S_{GAP\text{-}intg}$*=+82.5g*. The yearly GDP/c growth helps to mitigate, at least in part, the effects of the gap between the expected net socioeconomic benefits and the payments due to the financing formula, so the *T&S* of the *time profile of the modified intergenerational gap* is also positive, but its slope is less steep *(*$T\&S_{GAP\text{-}X}$ *=+79.1g)*. Only from the 12th generation $GAP_{X\text{-}i}$ values become positive. Finally, by considering the *intergenerational redistributive effects sharing index* value *(IRESI=0.32)* we conclude that H1 entails a moderate risk of intergenerational redistributive effects.

In scenario H2 the Project Developer is expected to private bank loans (bank funding) to guarantee the financing viability of the project. In this scenario the financing profile of the investment will correspond with the schedule of the deferred payments (cf. Figure III-9), which doesn't affect the time distribution of the net socioeconomic benefit flows.

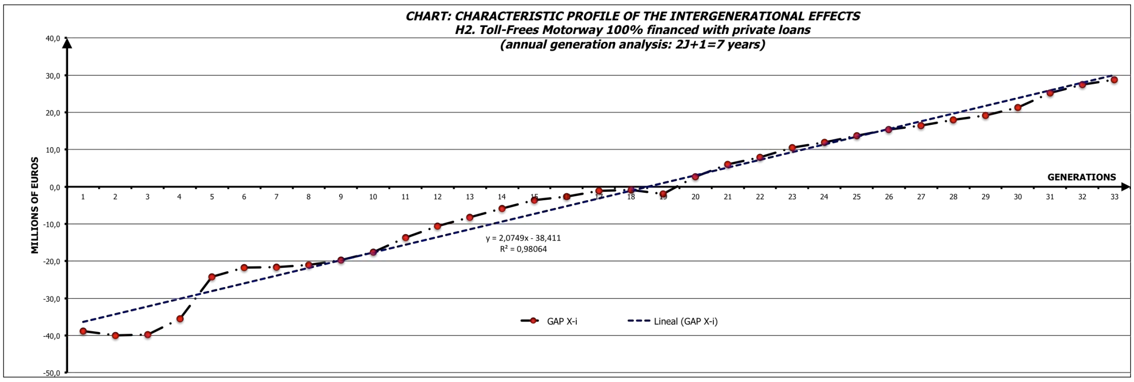
Figure III-9. Characteristic socioeconomic and financial time-profiles of the project (H2.Conventional bank funding)



Source: Author

From an intergenerational perspective, after generation 20th, the net benefits of the project would be much higher than the impact of the financial contribution (cf. Figure III-10), although redistributive effects are consistent *(*$R^2_{GAP[X]}$*=0.98)* and, in general, all generations benefit equally, that is, the risk that intergenerational redistributive effects due to the financing formula of the project is not significant *(IRESI=0.02)*.

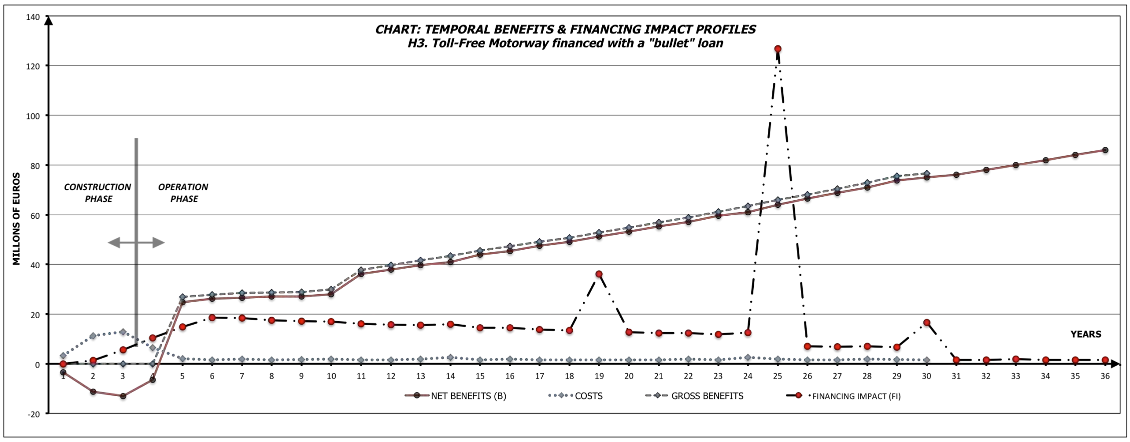
Figure III-10. Time-profile of the intergenerational redistributive effects (H2)



Source: Author

In scenario H3, on year 25th, the Project Developer will repay 50% of the borrowed capital *("bullet"* effect). The corresponding profile of the financial impact is shown in Figure III-11.

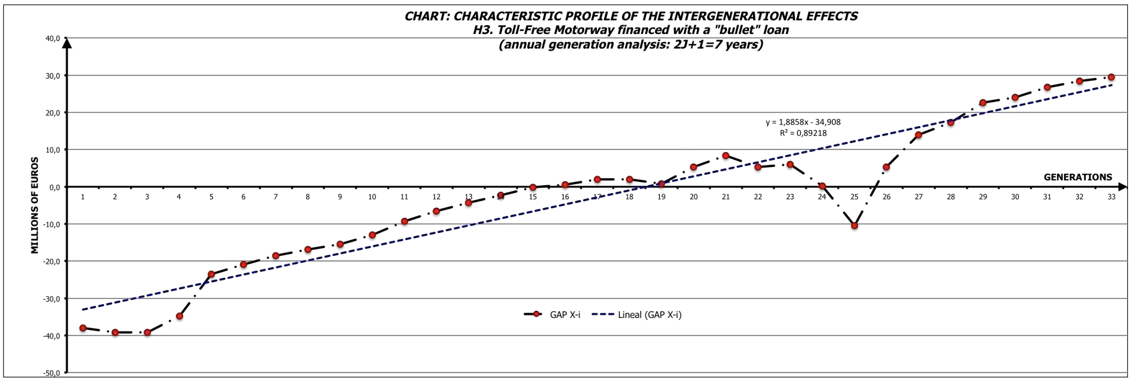
Figure III-11. Characteristic socioeconomic and financial time-profiles of the project (H3.Partial "bullet" loan)



Source: Author

When the main investment is financed using a *"bullet"* loan, the magnitude of the slope of *"GAP_{intg-i}"* and *"GAP_{X-i}"* series, *$T\&S_{GAP-intg}=2.43$ y $T\&S_{GAP-X}=1.89$* respectively, becomes, in comparative terms, almost as important than in the previous H1 scenario. As shown (cf. Figure III-12)*,* the intergenerational redistributive effects in scenario H3 are substantial *(IRESI=0.11).* They might be indeed important enough for paying attention to the impact of the financing formula on some specific generations (24th to 26th).

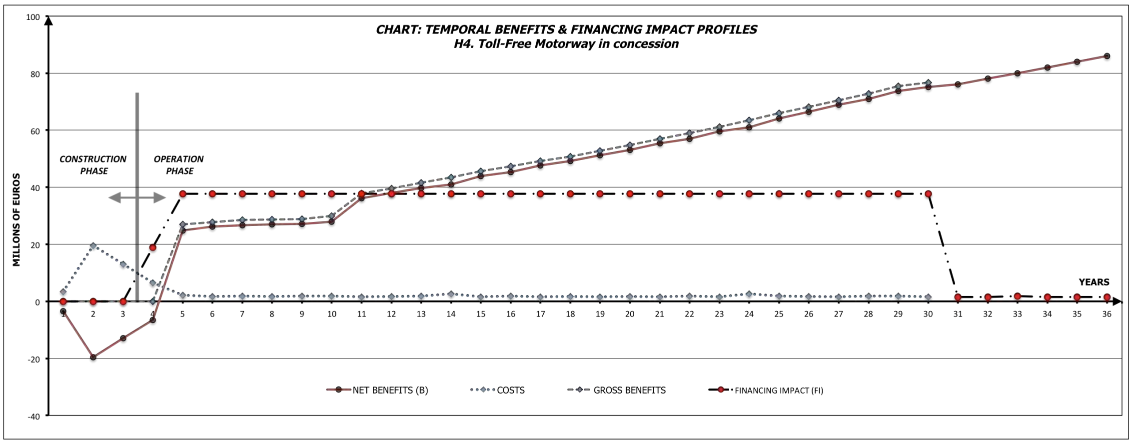
Figure III-12. Time-profile of the intergenerational redistributive effects (H3)



Source: Author

The scenario H4 corresponds to a PPP (concession) under the *Built-Operate-Transfer* modality, which was the financing formula chosen by the Government of Andalusia to carry out the project (cf. Figure III-13). The private concession holder assumes the risk of building and financing the transport infrastructure and maintaining it in service conditions according with the PPP agreement. As compensation, the private partner will receive recurring availability payments during the exploitation phase of the motorway, but assumes the risk of suffering penalties when quality standards are not met. Under these conditions the concessionaire company expects to obtain a NPV=203.9 M€ (discount rate 6%) and an IRR=12.1%. The discussion about the justification for the shadow tolls level will no be raised here, but it is important to understand that, being pure transfers, toll flows are not affecting the results of the CBA. On the other hand, the risk assumption by the private partner justifies that GPI will not include the investment as public debt and this is probably a main reason for the adoption of a PPP in this case.

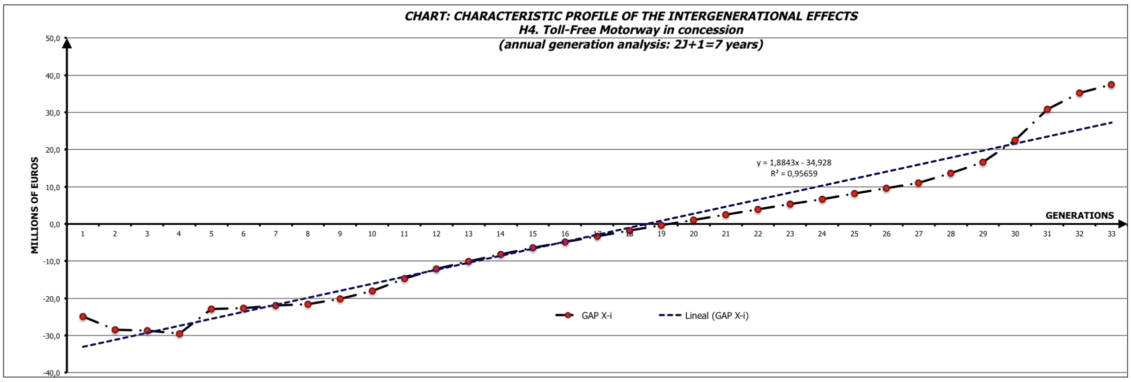
Figure III-13. Characteristic socioeconomic and financial time-profiles of the project (H4.Private concession)



Source: Author

As in previous scenarios, in H4 the trend of *"GAP_{intg-i}"* and *"GAP_{X-i}"* series is positive, but slopes *($T\&S_{GAP-intg}$=2.51 and $T\&S_{GAP-X}$=1.88)* are less steep than in the H1 and H2 scenarios. In this case the observed trend continues without showing significant variations because there is little volatility in the yearly gaps (cf. Figure III-14), so intergenerational redistribution effects are consistent *(IRESI=0.04)*.

Figure III-14. Time-profile of the intergenerational redistributive effects (H4)



Source: Author

The PPP system chosen by the Andalusian Government means users do not contribute to pay out the transport infrastructure. The socioeconomic benefits to road users are thus the only ones taken into account in the CBA carried out by GPI. Unfairness indicator (GUI) indicates in H4 that more than 35% of generations affected by the project will obtain socioeconomic net benefits lower than the financial burden they will borne, which is three times the GUI's value of the former hypothesis. Consequently, even taking into account that outcomes obtained in the analysis of the intergenerational redistribution effects appear acceptable (cf. Table III-3), if the net benefits do not grow as expected, for instance due to optimistic demand forecasts, the trend of the *"GAP_{X-i}"* series could become flat or even negative. In this case, the financing formula adopted would require a specific justification.

Table III-3. Summary of the intergenerational analysis of the motorway A-334 project

Outputs of the GAP_{X-i} series	FINANCING FORMULA SCENARIOS			
	H1. Budgetary	H2. Long Term Loan	H3. *"Bullet"*	H4. Concession
GUI	12.1%	12.1%	12.1%	36.4%
T&S	+79.1g	+71.4g	+69.0g	+68.9g
IRESI	0.32	0.02	0.11	0.04

Source: Author

7. CONCLUSIONS

Traditionally, the financing formula for an infrastructure project is only taken into account once the assessment of its viability has been completed. Quite often the adopted formula responds to constraints that are not responding to efficiency or equity considerations. It could, however, severely affect many of the objectives that were essential to the initial considerations for its construction. A main aspect in any major project is who will end up paying for it. Curiously enough, the intergenerational effects due to the different possible financing structures have not been properly addressed until now.

The IREM model that has been proposed provides a set of indicators allowing decision-makers to easily understand the importance of the intergenerational effects associated to the financing formula of an investment project. It is based on the comparison between the yearly net socioeconomic benefits obtained from the cost-benefit analysis and the yearly payments made by the various agents participating in the project, essentially users and taxpayers. By comparing both time profiles, and adjusting them to the context conditions, it is possible to produce a time series of the gap between them and calculate four indicators: the *Generational Unfairness Indicator (GUI)*, which gives the percentage of *"AG_i"* with negative gaps over the total, the *trend* of the *gap* series (increasing or decreasing), the *slope*, which indicates its importance, and the *Intergenerational Redistributive Effects Sharing Index (IRESI),* which reflects concisely whether there is a strong variability among the generations considered in the project cycle. From them it will be easy to determine whether the potential intergenerational effects of the project will be substantial and, where appropriate, to take them into consideration for adopting decisions about the financing system to be chosen by the promoter of the transport infrastructure.

With the proposed IREM model, a motorway promoted by the Government of Andalusia (Spain) has been evaluated, taking into account for it four different financing formulae. This is an empirical work only as an illustration of how to implement the indicators of intergenerational redistribution effects. In these four hypotheses the standards of quality, durability and stability of the project do not change, regardless of the management system. The *"generational unfairness indicator"* for the Hypothesis 1 to 3 *(GUI=12%)* confirms that some generations (annual generations from 1 to 4) are paying more than the net benefits they receive from the investments in transport infrastructure. However, the *GUI* for the Hypothesis 4 is particular high since a 36% of the annual generations will pay more than they receive from the investment. The value of the *"Trend&Slope"* for the set of Hypothesis *(+79<T&S<+69g)* further indicates that transport infrastructure projects tend to benefit future generations (certainly overlapped) within the project timespan.

The Government of Andalusia opted for a PPP system (concession) to carry out the investment. The application of the IREM model to the case has shown that the redistributive effects across generations do not seem important *(IRESI=0.05)* with the adopted financing solution. Other formulae could, however, imply more substantial intergenerational effects and require a particular attention from the decision-maker.

8. REFERENCES

- Angelsen, A., 1991. *Cost-Benefit Analysis, Discounting, and the Environmental Critique: Overloading of the Discount Rate?* Report 1991:5. Bergen: Deparment of Social Science and Development Chr. Michelsen Institute.
- Arrow, K. et al., 1995. Intertemporal equity, discounting and economic efficiency. In al., B.e. Climate change. Cambridge, UK: Cambridge University Press. pp.128-44.
- Arrow, K. et al., 2004. Are we consuming too much?. *Journal of Economic Perspectives* , 18(3), pp.147-72.
- Arrow, K. & Kurz, M., 1970. *Public Investment, The Rate of Return, and Optimal Fiscal Policy*. Washington, DC: Resources for the Future.
- BdE, 2012. *Crecimiento a largo plazo y perspectivas demográficas en las economías avanzadas*. Boletín Económico. Banco de España.
- Blanchard, O.J. & Fischer, S., 1989. Lectures on Macroeconomics. *MIT press*.
- Eckstein, O., 1958. *Water Resource Development: The economics of project evaluation*. Cambridge, MA: Harvard University Press.
- Evans, D. & Sezer, H., 2004. Social discount rates for six major countries. *Applied Economics Letters*, 11, pp.557-60.
- Feldstein, M.S., 1964. Time Preference Discount Rate in Cost Benefit Analysis. *The Economic Journal*, 74(294), pp.360-70.
- Fernández-Baca, 2011. *Actualilzación de la Tasa Social de Descuento*. Informe Final. Madrid: Dirección General de Programación Multianual del Sector Público del Ministerio de Economía y Finanzas de España.
- Gahvari, F. & Micheletto, L., 2014. The Friedman rule in an overlapping-generations model with nonlinear taxation and income misreporting. *Journal of Public Economics*, 119, pp.10-23.
- Gollier, C., 2011. *Pricing the future: The economics of discounting and sustainable development*. Princeton University Press.
- HM Treasury, 2003. *The Green Book: appraisal and evaluation in central government: Treasury guidance*. Stationery Office.
- Kotlikoff, L.J. & Burns, S., 2005. *The coming generational storm: What you need to know about America's economic future*. London, England: MIT Press.
- Laibson, D., 2003. *Intertemporal decision-making*. London: Nature Publishing Group.
- Marglin, 1963. The social rate of discount and the optimal rate of investment. *Quarterly Journal of* Economics, 77(1), pp.95-111.
- Meunier, D., Quinet, A. & Quinet, E., 2013. Project apparisal and long term strategic vision. In *41st* European *Transport Conference*. Frankfurt, 2013. Elsevier.
- Moore, M. et al., 2004. "Just Give Me a Number!" Practical Values for the Social Discount Rate. *Journal of Policy Analysis and Management*, 23(4), pp.789-812.
- Penyalver, D. & Turró, M., 2016. Intergenerational Redistributive Effects of Transport Infrastructure Financing. Case Studies from European and Non-European Countries. STAREBEI Report. Available online at: http://institute.eib.org/map/map.html
- Phelps, 1961. The golden rule of accumulation: A fable for growthmen. *American Economic Review*, 51(4), pp.638-43.
- Ramsey, F.P., 1928. A mathematical theory of saving. *Economic Journal*, 38(152), pp.543-59.
- Romer, P.M., 1986. Increasing Returns and Long-Run Growth. *Journal of Political Economy*, 94(5), pp.1002-37.
- Romer, P.M., 1990. Endogenous Technological Change. *Journal of Political Economy*, 98(5), pp.S71-S102.
- Romer, D. & Chow, C., 1996. *Advanced Macroeconomic Theory*. McGraw-Hill.
- Samuelson, P.A., 1958. An exact consumption-loan model of interest with or without the social contrivance of money. *The Journal of Political Economy*, 66(6), pp.467-82.
- Scaborough, H., 2011. Intergenerational equity and the social discount rate. *The Australian Journal of* Agricultural *and Resource Economics* , 55(2), pp.145-48.
- Scaborough, H. & Bennet, J., 2008. Estimating intergenerational distributional preferences. *Ecological* Economics, 66, pp.575-83.

- Solow, R.M., 1956. A contribution to the theory of economic growth. The quarterly journal of economics. The Quarterly Journal of Economics, 70(1), pp.65-94.
- Soman, D. et al., 2005. The Psychology of Intertemporal Discounting: Why are Distant Events Valued Differently from Proximal Ones? Marketing Letters, 16(3/4), pp.347-60.
- Souto, G., 2003. El descuento social. *Hacienda Pública Española/ Revista de Economía Pública*, 165(2).
- Stiglitz, J.E., 2013. The Rate of Discount for Benefit-Cost Analysis and the Theory of the Second Best. *Discounting for Time and Risk in Energy Policy*, 3, p.151.
- Weiss, L.M., 1980. The effects of money supply on economic welfare in the steady state. *Econometrica*, 48, pp.565-76.

SECTION IV. INTERGENERATIONAL PERCEPTION OF THE UTILITY OF MAJOR TRANSPORT PROJECTS

Penyalver, D., Turró, M. & Zavala-Rojas, D, 2018

Abstract

A basic question for the assessment of the fairness of a project financing formula on successive generations is to determine what is the most appropriate method to group the affected individuals over the years. The generational approach in the *"Intergenerational Redistributive Effects Model"* (IREM) deals with it through the ad-hoc concept of *overlapping annual generations*. This concept requires establishing the number of years (or timespan) included in the generation and how to incorporate in it those individuals living in years that are not the central one. To do so in a way that reflects the sensitivity of society to the effects of a major transport infrastructure, specific surveys with an approach novel have been designed. The outputs from the survey carried out in Catalonia show evidences suggesting that discount functions should tend to decline at a higher rate in the short term than in the long term. Thus, future impacts of transport investments, both future socio-economic net benefits and financial burdens, should be considered less important than immediate (present) outcomes in decision-making process. Further, there are reasons to consider that discounting is not neutral to reflect the social interest of large-scale transport projects for the successive generations involved.

1. INTRODUCTION

Understanding how people perceive, evaluate and undergo the effects of major investments should be particularly relevant for decision makers. To a large extent, people's preferences and their support to investment decisions depend, among other factors, on their experiences and expectations on the positive and negative outcomes that may result from investments with capacity to constraint individuals' future choices (Lewis, 2001; McLachlan & Gardner, 2004). For example, when dealing with major investments enhancing mobility in congested areas, the well-known benefits (travel time savings, environmental positive impacts from reduction in pollution, etc.) that are immediately perceived are frequently more important for individuals that the costs and benefits that are uncertain, delayed or that might occur to others elsewhere (Gatting & Hendricks, 2007).

The financial structuring of the investments that the society "of each moment" requires is also of great importance. At the macroeconomic level, disposing of money to pay for the construction of an infrastructure project will affect public accounts and divert funds from other potential uses. At the microeconomic level, the financial structure determines who will end up paying for the investment. As this structure typically adjourns actual payments through credit facilities, it affects future cash flows and, as a consequence, it has intergenerational impacts. These impacts can be assessed through a model that compares the allocation of net socioeconomic benefits over time with the flows of obligations (in terms of payments) arising from the financing formula. The effects that are identified using the *Intergenerational Redistributive Effects Model or IREM* (Penyalver & Turró, 2017) may have strong impacts on the social welfare of generations to come and should thus be considered in the decision-making process.

The paper explains the process followed to identify the perception of the citizens on the effects on the welfare of their generation and on future ones of major investments in infrastructure. This perception is essential for the definition of the concept of *"annual generation"*, which is critical for the IREM. The paper explains the issues that led to the development of IREM and the use of a specific survey to determine some key parameters of the model. Surveys are essential for gathering data in the applied social sciences (Groves et al., 2009). In this case it was necessary to place the respondent in a forthcoming situation to obtain her appreciation of the impact of major transport infrastructure projects on someone living in the future. The work represents a first step into the incorporation, with a degree of objectivity, of the redistribution effects of such infrastructure projects on the multiple generations affected.

2. THE INTERGENERATIONAL EFFECTS OF MAJOR PROJECTS

The decision-making process for major infrastructure projects focuses on selecting those that represent the best use of resources for society. Feasibility studies are expected to estimate the socioeconomic profitability of a project, which is the key indicator of its efficiency. This profitability is calculated using classical economic models[1], which assume that a single theoretical welfare-function can adequately represent the preferences of the different (overlapped) generations bearing the costs and the benefits of an investment. The balance between these costs and benefits is referred to the moment of the analysis through discounting. Properly applied, discounting is useful to establish how much future benefits and costs are worth today (static perspective). In essence, the future utility of an infrastructure investment is assumed

[1] Cost-Benefit Analysis (CBA) is the microeconomic model traditionally used to measure efficiency for major infrastructure projects. The main outcome from CBA is the Economic Net Present Value (ENPV), which is limited to the costs and benefits that can be monetised and entails using a suitable social discount rate (SDR).

to be the additional social welfare generated during the project lifecycle, measured through the economic net present value (ENPV).

A critical point in the discussion about the assessment of the long-term effects of certain investments in civil infrastructure projects, such as nuclear plants, which have obvious impacts on future generations, is whether the method of discounting and/or the value of the social discount rate in Cost Benefit Analysis (CBA) lead to the right conclusions in terms of efficiency for all the people affected over the project life. Discounting methods of long-term effects are problematic because some people's values and preferences are treated differently because they live at different times (Lee & Ellingwood, 2015). In the discussions on discounting the concept of intergenerational redistributive effects is, nonetheless, absent in spite of the clear differential impacts across generations of certain long-run effects (e.g. climate change) of major investments with long timespans (50, 100 or more years).

Properly placing the project effects over time is essential for ENPV calculations. This requires estimating the preferences of the affected individuals. Preferences may be analysed with standard methods when framed in relatively short-term time horizons and within an intragenerational context. Integrated investment programmes and major infrastructure projects must be placed, however, in an intergenerational context, which addresses extremely long-term horizons and the impacts on and preferences of unborn generations (EPA, 2016). The distinction between both contexts is important to establish whether the method of discounting is suitable to adequately represent the impacts of major projects and, if so, which social rate of time preference should be used in each case (Groom et al., 2005). The conflicts between intragenerational and intergenerational effects are often set up under the perspective of the sustainable use of natural resources. It can be argued, though, that the redistribution effects across generations should go beyond this and also consider a fair split of economic and financial impacts.

The consideration of intergenerational effects on decision making –in principle through a kind of multicriteria analysis– is more justified when dealing with major infrastructure investments[2], as they mobilise huge amounts of economic resources, are prone to complex financial structures, including public-private partnerships (PPPs), and have very long project cycles. In this type of investments, the government promoting the investment (GPI) may use a wide range of management systems and funding options to develop the project[3]. These options will determine the relationship between the net socioeconomic benefits during the operation of the project and the actual end-of-the-line payments for its construction. To help understanding the issue, it is worth to imagine a situation where the whole investment is financed by the GPI through a bullet loan[4]. Those individuals belonging to the generations at the end of the loan cycle would end up bearing most of the financial costs, unless they are able to refinance the loan[5], whilst their net benefits in terms of resources would probably be even less than average due to congestion, poorer performance, etc., and very uncertain besides. The particular aspects of transport infrastructure investments are therefore most adequate to analyse intergenerational effects.

[2] The IREM model used in the research has been applied essentially to transport infrastructure projects.

[3] The GPI may fund the investment directly through its annual budget or using bank loans (that will be repaid using budget funds), or may decide to delegate the management of the project to a public Agency or Company. The GPI may also decide developing the project by means of a public-private partnership, including a pure concession. A key issue is how users will pay for the use of the infrastructure.

[4] It is a loan where the repayment of the entire principal, sometimes even the principal and interest, is due at the end of the loan term.

[5] In any case the burden of refinancing will fall upon them.

IREM has been specifically developed to analyse whether there exists a balanced distribution between the socioeconomic net benefits and the financial burden over time for the different overlapping generations concerned by the project. IREM's outputs should only be analysed, however, in terms of fairness/unfairness[6]. Efficiency is, in principle, assessed from the CBA, using an adequate social discount rate (SDR). But overall efficiency does not take into account how the project is financed (as financial cash-flows are essentially transfers that are not affecting the Cost-Benefit Analysis or CBA, although they are often used to value resources). The intergenerational analysis is complementary to the CBA and provides a view of the fairness of the actual financial payments for the project across the various generations affected. This analysis requires both defining a "generation" and an ad-hoc utility function that reflects the economic preferences of this generation. This estimation process is the object of this paper.

3. OBJECTIVES OF THE RESEARCH

A main challenge in the elaboration of the IREM model was incorporating how citizens perceive their integration in a particular generation when it is concerned by an infrastructure project with a very long time projection and how citizens, placed within their own generation, apprehend the effects of such a project both in terms of its benefits and the predisposition to pay for them. Conventional surveys place the respondent in the present or in well-defined future contexts. In our case it was necessary both to place the respondent in a complex future situation and as part of a group of people who would be affected by the project over time. This required a new approach in the preparation of the questionnaire and in the quantification process. The cooperation between psychologists and project specialists (engineers, economists, financiers) was essential to prepare the questionnaires and to analyse the outcomes of the survey. The results of this research show the importance of a multi-disciplinary approach in developing tools for project appraisal.

This paper focuses on the work carried out to: 1) establish the most suitable timespan to properly represent a generation in the IREM, and 2) define a utility function that represents society's preferences within each generation according to the main features and effects of major infrastructure projects. After these introductory chapters, Section 4 reviews the main features of the utility functions characterising the collective preferences in the allocation of consumption across generations[7] in the traditional economic approach. Section 5 contains a brief presentation of the generational concept used in the IREM model to assess the fairness of a project financing formula on successive generations. Section 6 presents the methodology followed for designing and conducting the survey carried out in Catalonia to estimate the parameters of the model in a real context and its main findings. Here, the parameters that define a generation linked to major transport projects are introduced. Finally, in Section 7, the main conclusions of the research are highlighted.

[6] The "fair/unfair" concept refers to moral obligations towards future generations (Rawls, 1972). It is considered that human cooperation is possible and necessary for coexisting individuals on a specific territory, but also across territories and across individuals living in different time spans (generations).

[7] Traditional macroeconomic approach assumes implicitly that the generational concept has a genealogical meaning.

4. INTERTEMPORAL CHOICE MODELS REVIEW

The discounting mechanism and the SDR are critical in determining the social value of major investments in infrastructure. They both make up the function that in CBA transforms future costs and benefits into an ENPV for the generation in which the decision is taken. ENPV is a key indicator of the project's efficiency from the perspective of the overall society of the time of the decision to build[8]. SDR, on the other hand, explains how decision makers perceive the propensity of present generations to renounce to immediate consumption in order to have the possibility to consume more in the future and thus an indication of how public resources are used to maximise the welfare of the citizens affected by the investment over its project cycle.

The theoretical framework of the SDR comes from the Ramsey Model (Ramsey, 1928). Social welfare can be conceptualised through a function (W_t) representing its dynamic of change that, in turn, is represented by the intertemporal sum of the utility that a person obtains from individual consumption.

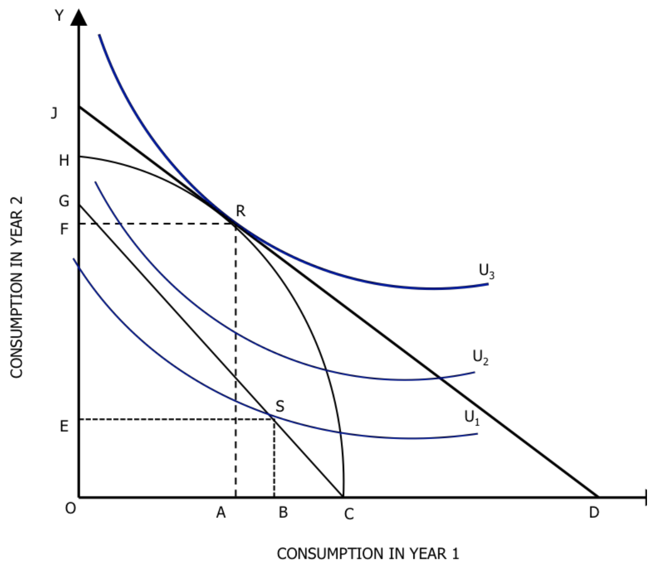
Equation IV-1. Dynamic Social Welfare Function

$$W = \int_0^{\infty} W_t \cdot e^{-rt} dt$$

- $W_t = U(C_t)$ Value of welfare on each *"t"* period in terms of utility from individual consumption
- $r = \log_e(1+i)$; Continuously rate of discount/interest (Samuelson, 1937)
- i Rate of discount/interest per unit of time

Graphically, it is possible to build up a preference function from the concept of indifference curve introduced by Irving Fisher (cf. Figure IV-1).

Figure IV-1. Optimum inter-temporal choice scheme



Source: adaptation from Feldstein (1964)

The X axis represents the individuals' consumption in year 1 from the available annual budget. The Y axis represents the amount saved for future consumption in year 2. The line CG represents the consumer's possible use of the budget for year 1. Its slope *m* is frequently referred as the Consumption Rate of Interest (CRI); $CRI = -(m+1)$.

[8] The time when the project is formally given the go-ahead (Flyvbjerg, 2005). When this date is not available or representative, the date of project approval by the main financiers can be adopted as the time of decision.

For a particular income level the indifference curve *'U_i'* represents the relationship between two amounts of different goods that entail the same satisfaction degree for consumers (Fisher, 1930). The more income the higher ability to obtain goods, and thus the curve moves from U_1 to U_2, U_3… For an investment, the question of interest is to determine how much consumption in the present will become consumption in a second period of time taking into account its expected utility. Curve CH shows the real opportunities of transforming present consumption into future consumption through investment. Its slope represents the social productivity of investment for society as a whole, which is expressed through the internal rate of return of the capital invested. The marginal efficiency of capital between two consecutive years decreases with the investment amount. Assuming $U(C_t)$ is time invariant, its first derivate is $U'>0$ and $U'' \leq 0$, and CRI is defined as the rate at which the marginal welfare of consumption falls over time:

Equation IV-2. Consumption Rate of Interest

$$CRI = -\frac{(dW_{ct}/dt)}{W_{ct}}$$

~ W_{ct} Welfare effect of a marginal increase in the consumption in period t

A multitude of factors could have influence on the value of CRI. On the one hand, individuals may consider that the consumption satisfying present needs is more useful that the same consumption in a period afterwards (decreasing marginal utility of consumption), which can be explained by a question of impatience or immediacy (Pigou, 1920; Ramsey, 1928; Harrod, 1948) and certain aversion to the risk involved in postponing consumption (Pratt, 1964; Arrow, 1970). Some individuals could even take into account their own probability of death at the moment of making decisions about consumption/saving (Angelsen, 1991). In sum, although pure time preference is heterogeneous among the agents within an economy (Gollier & Zeckhauser, 2003), the former arguments justify considering time consumption preferences at the moment of establishing the value for SDR (Tinbergen, 1956; Eckstein, 1961; Scott, 1977; Scott, 1989).

According to the Ramsey Rule, SDR encompasses society's pure-consumption preferences (social value) and other factors related to the social productivity of collective investments for society (opportunity cost for society or social cost).

Equation IV-3. Ramsey Rule

$$r = \rho + \theta g = \delta$$

~ g Growth rate of consumption. As it is expected some economic growth over time, it is assumed that $g>0$.

~ θ Elasticity of inter-temporal substitution (marginal utility of consumption): it is a measure of the curvature of the utility function, and is mathematically equivalent to the coefficient of relative risk aversion; $\theta = -\frac{U"}{U} C_t$. $\theta>0$. High "θ" implies a strong preference for consumption now rather than in future periods. If $\theta=0$, the welfare increase of one monetary-unit extra income to the consumer is the same regardless of his initial consumption.

~ ρ Rate of time preference of consumption; $\rho > 0$ implies that individuals prefer early consumption to later consumption, even if the consumption level is the same.

Equation IV-3 shows the relationship between the social rate of time preference (δ), the "utility discount rate" or rate of pure time preference (ρ), and the social rate of return to investment *(r)*, which matches with the private return to investment *(i)* in absence of externalities and other distortions (Groom et al., 2005). Each of these rates is a contender for use as the SDR, where the appropriate discount rate for use in CBA depends upon the numeraire employed (Groom et al., 2005).

Combining factors g and ρ it is possible to obtain different values for SDR. As shown in Table IV-1, with positive growth and concave utility the SDR will be positive. In this case, discounting consumption streams in CBA can be synonymous with the equal treatment of generations' welfare (Lind, 1995).

Table IV-1. Different cases for the function of discount rate

	$\rho > 0$	$\rho = 0$
[1] $\theta g > 0$	*CRI > 0*	*CRI > 0*
[2] $\theta g = 0$	*CRI > 0*	*CRI = 0*
[3] $\theta g < 0$	*?*	*CRI < 0*

Source: adaptation from Angelsen (1991)

Positive values for SDR do not imply ρ>0, which means that the individuals' pure time-preference might or not vary over time. Actually, if the marginal utility rate of consumption *(g)* is not regressive for individuals, the future effects will be less important than those at the moment of the analysis, independently of the consumer's time preferences. On the other hand, if $\rho > g$ or $\rho \sim 0$, individuals could prefer immediate consumption and have therefore lower propensity to save, which from a collective perspective can lead to postpone investments and to reduce the flow of benefits for future generations. This collective behaviour would imply a negative impact on future generations (Olson & Bailey, 1981; Moellendorf, 2014). Finally, as θ represents preferences for smoothing consumption over time, high values of θ would be correlated to (comparatively) small ones for the marginal utility rate of consumption *(g)* and vice versa (Dasgupta, 2007).

In conclusion, from a theoretical perspective, the SDR value should reflect both society's preference for present consumption rather than future one (social value approach) and the yield that could be obtained from the economic resources spent in a project in the best alternative investment (social cost approach). However, both values for the SDR could be quite different (Feldstein, 1964; Arrow & Kurz, 1970; Angelsen, 1991; Laibson, 1997; Souto, 2003; Arrow et al., 2004; Moore et al., 2004; Roumboutsos, 2010; Fernández-Baca, 2011; Gollier, 2011).

In the first approach, the discounting method transforming future socioeconomic costs and benefits into present values does not have to adopt necessarily a constant discount rate. In the social cost approach, the opportunity cost for society is associated to the private return to investment (i), reflecting the perception of the average member of society, which undoubtedly has a more or less conscious relation with the financial interest rates. In this approach, to estimate the SDR for CBA it is assumed that resources can be distributed through generations, through investments in infrastructure assets having maturities limited to 30-40 years being financed by mechanisms that meet the requirements of financial markets (Lee & Ellingwood, 2015). But there are multiple funding sources of capital and a variety of financing instruments (bonds, loans, tailored facilities, etc.), different risk perceptions, a volatile money supply, etc. that imply, not only a broad range of interest rates for long-term assignment of money, but strong variations in these rates in the capital markets over the years. In any case, the rate of return for private capital is hardly representative of the social values that the SDR implies. Financial markets focus on maximising private benefits, keep a clear general risk aversion and show an opportunistic behaviour[9] (von Hagen et al., 2011), and their expectations seem to have little correlation with society's willingness to delay consumption.

[9] It is obvious when observing bond yield spreads in the various EU countries during the financial crisis

On the social value approach the estimation problems are also overwhelming, because it is practically impossible to estimate the return of the great number of opportunities foregone, which depend on the sector, investment amounts, etc. The solution adopted by most administrations is to take into consideration both aspects (social value and social cost) and adapt the rate of return to private capital, whatever the means to calculate it, through a "shadow value" (Feldstein, 1964).

Thus, it is not possible to speak of a single 'appropriate' discount rate but of an efficient discount rate[10]. This rate should (ideally) reflect both the social value and the social opportunity cost of project development but, in practice, the choice of the "appropriate" SDR for a given project or project sector has been defined by the public administrations in order to achieve certain policy objectives (Henderson & Bateman, 1995; HM Treasury, 2003; Evans & Sezer, 2004; Leleur et al., 2007; Meunier et al., 2013).

The decision on the SDR value to be used is critical in determining which projects will pass a CBA test. The potential influence of the SDR in long-term investments, with benefits and cost accruing over several generations, is particularly strong because even small changes in the discount rate have a significant impact on the indicators supporting decision-making (Lee & Ellingwood, 2015). Following the rational choice theory, discounting methods usually employ an exponential discount function (Laibson, 1997; Coleman & Fararo, 1992; Frederick et al., 2002; Gollier et al., 2008). Under the usual SDRs, the costs and benefits accruing to generations in the distant future appear relatively unimportant in present values terms.

In formal discounting models it is assumed that consumer's welfare can be represented as a discounted sum of current and future utility (cf. Equation IV-4). Thus, that utility can be referred to as consumption or income (Samuelson, 1937; Arrow & Kurz, 1970; Arrow et al., 1995; Laibson, 1997; Gollier, 2011; Arrow et al., 2014; Freeman et al., 2015).

Equation IV-4. Ramsey's generalised discounted model (Laibson, 2003)

$$W \equiv U_t = \sum_{\tau=0}^{T-t} D(\tau) \cdot u_{t+\tau}$$

- U_t Total utility from the perspective of the current period (year) *"t"*
- $D(\tau)$ Adaptation to year 0 of the welfare of the consumer occurring at time "τ"; sometimes called objective utility function or "discount function". The higher the discount rate[11] the greater the preference for immediate benefits over delayed rewards.
- $\tau \equiv \Delta t$ Time period used to discount the utility series until the horizon year at the frequency "Δ".
- T The last period considered (for example, the last year in the lifecycle of an investment)
- $u_{t+\tau}$ Utility of consumption in period *"$t + \tau$"*, sometimes referred to as instantaneous utility or felicity

[10] The efficient discount rate can be estimated in three different ways: as the continuously changing rate of interest from financial markets, as the marginal rate of return on productive capital in the economy, and as the welfare-preserving rate of return on savings (Gollier, 2011). The rate to be obtained from reinvestment of returns and the risk differences between private and public investments have also been considered determinants of the socially efficient discount rate (Baumol, 1968). Even if we were able to estimate these values, it seems evident that we cannot speak of a single appropriate discount rate (Stiglitz, 2013).

[11] It is not, however, the discount rate used by economists to discount future cash flows, although there is a link between both.

In Equation IV-4, the total utility *(U_t)* is an additive function. The benefits obtained of immediate consumption have no effect on the utility of the benefits obtained afterwards. Otherwise, incongruence from time inconsistency results in consumption and saving plans that are sub-optimal for all generations (Weitzman, 1998). Whilst it is assumed that the consumers' preferences do not change over time, granting the property of time consistency, discounting utility at a constant rate *(ρ)* insures that the mechanisms that constitute the basis of decision-making are also time consistent (cf. Equation IV-5). This assumption known as *time consistency* or *dynamic consistency* allows isolating time 0 and time t in the welfare-preserving discount rate evaluation: in time $t=0$, preference reaches its maximum $D(0)=1$. For $t>0$, the discount function slopes down as time increases, $D'(t)\leq 0$. Therefore, $1 = D(0) \geq D(t) \geq D'(t) \geq 0$, with $??(t)=-D'(t)/D(t)$ being the rate at which the discount function declines.

Equation IV-5. General expression of the exponential discount function (Laibson, 2003)

$$D(t) = \lim_{\Delta\to 0}\left(\frac{1}{1+\Delta\cdot\rho(t)}\right)^{1/\Delta} = e^{-\rho(t)} = \delta^t$$

A second body of research argues, however, that choice behaviour is largely inconsistent (Little, 2002). For some authors, discounting utility appears 'ethically indefensible', 'rapacious' and 'defective' from an intergenerational perspective, in spite that, under certain conditions (context), it can be useful to reflect how society's time preferences decline (Ramsey, 1928; Harrod, 1948; Freeman & Groom, 2014). Since economists' conclusions about economic welfare incorporate consumers' behaviour in a timeless manner (Little, 2002), *«decisions made today on the basis of CBA appear hence to tyrannise future generations and, by extension, discounting appears to be contrary to the widely supported goal of sustainability»* (Arrow et al., 2013). This occurs because, on the one hand, time preferences vary due to uncertainty and to other contextual factors, such as price fluctuation of goods and services (Coleman & Fararo, 1992; Frederick et al., 2002; Groom et al., 2005; Gollier et al., 2008; Arrow et al., 2013; Arrow et al., 2014; Freeman et al., 2015) and, on the other hand, market prices do not exist for many of the determinants of utility such as environmental assets. In this sense, the theoretical framework for intertemporal choices modelling resembles the one used in business, which applies a compound interest formula, and does not adequately reflect the collective preferences over time (Frederick et al., 2002).

Research shows that individuals prefer a smaller but earlier reward than a larger reward coming later in time (Kirby & Herrnstein, 1995). According to this, the SDR over longer time horizons should be lower than over shorter ones (Frederick et al., 2002), implying that costs and benefits should be discounted at higher rates in the short run than in the long run (Frederick et al., 2002; Laibson, 2003; Soman et al., 2005; Arrow et al., 2014).

A recently proposed solution to estimate discount rates for the very long-term, which is the case of investments encompassing very large timespans whose costs and benefits entail high degrees of uncertainty (e.g., high speed railway networks development, nuclear power, etc.), is to use a declining discount rate (DDR) according to some predetermined trajectory. There is no consensus, however, on how to apply this solution. On the one hand, declining utility discount rates may produce time inconsistent planning (Groom et al., 2005). Whilst dynamic inconsistency, i.e. violating the assumption of time consistency, has been successful to explain some phenomena in the behavioural economic literature, e.g. procrastination and addition (Harris & Laibson, 2001), the welfare measured in terms of the utility for society cannot be maximised in a process where the discount rate changes as time moves on (Groom et al., 2005). On the other hand, in a declining model the rate of decline usually adopts hyperbolas and quasi-hyperbolic functions (Herrnstein, 1961; Mazur, 1987; Ainslie, 1992; Loewenstein & Prelec, 1992) showing much higher discount rates in the short-term than in the long-term, when they remain relatively constant. Therefore, to determine the schedule of DDRs it is necessary to make some assumptions concerning the point in time at which uncertainty concerning the discount rate begins (Weitzman, 1998) as well as to calibrate the trajectory that a DDR has to follow from this point (Newell & & Pizer, 2003; Groom et al., 2005).

What is more widely agreed is an arbitrage between exponential discounting and declining discounting through an equivalent SDR, although it appears more useful as a way of determining the maximum ENPV of investments rather to compare different alternatives to solve the same problem (Weitzman, 1998; Groom et al., 2005; Lowe, 2008; Freeman & Groom, 2014; Freeman et al., 2015). The use of an equivalent SDR is especially adequate where the effects under examination are very long-term and involve very substantial and, for practical purposes, irreversible wealth transfers between different genealogical generations (Lowe, 2008).

In short, there exist different approaches to determine the social value of major investments in infrastructure. They focus on optimising the discounting process to offer "present" decision-makers the most suited value of SDR. According to the time consistency approach, exponential discounting through a constant SDR may be appropriate to determine with rigour the maximum utility of project decisions in the short run (Lind, 1990). For long-term investments, declining discounting by using a DDR or an equivalent SDR is an option that allows taking into account collective preferences over time more adequately (Henderson & Bateman, 1995). However, whilst this approach can be optimal for the current GPI, it can result in a sub-optimal (time-inconsistent) use of public resources from the perspective of successive governments (Barro, 1999; Karp & Lee, 2003).

From the former considerations it can be argued that current discount models are not properly analysing the impact of investments implying large timespans and affecting different generations. The simple aggregate of benefits and costs does not offer information about the resulting redistribution of wealth (Bradford, 1997) and, in particular, across the generations affected by the project. Discounting and SDR are useful in CBA to determine the most efficiency alternative for a project from a static present-time perspective, but they appear inadequate to incorporate the interests of future generations, which will undoubtedly be affected by the impacts that present investments in transport infrastructure will have on their welfare.

5. THE GENERATION CONCEPT IN THE IREM MODEL

Investment projects are typically analysed through a socioeconomic CBA that considers the use of resources, so they are assigned to the period (year) when they are consumed (costs) and generated (benefits). On the other hand, the financial analysis looks at the expected cash flows and at the money inputs and outputs of the various stakeholders, among them the users of the project if they are directly contributing to its financing. The objective is to make sure that funding is available for the implementation of the project and that no major stakeholder will be the subject of financial failure as a consequence of the investment; to ensure financial sustainability. In general, these two analyses are carried out separately and are often improperly mingled.

The welfare considerations, as already mentioned, are made from the perspective of the present generation, but even though the investment resources, such as those used in the construction of the infrastructure, are "lost" by the society in place during the implementation, the actual effects on people's welfare are mostly perceived when they have to pay for these resources either through user charges or through taxes. So, when analysing the fairness of the distribution of actual costs and benefits (welfare) across the generations affected by the project, it is necessary to look on the one hand at the net benefits in terms of resources during the relevant period and the amounts paid during this period for the use of the project (tariffs, tolls, etc.) and as a contribution to its financing, which clearly depends on the funding mechanism applied, in particular the distribution of the public budget used to pay for the investment directly or through loans.

In practice the budget payments for public investments (or private investments requiring public subsidies) are embedded in the public accounts and this is probably why the issue of the fairness of intergenerational distribution has been somehow absorbed by the major problem of the long-term effects of public debt. However, when decisions must be taken at project level, the effects of the funding mechanism on intergenerational fairness seem relevant. To make a proper assessment of these effects across the generations it is necessary to compare the net benefits arising for each of them with the actual payments they make in relation to the project either as users and/or taxpayers. IREM provides a suitable approach to deal with the incorporation of this critical aspect for major infrastructure investments which has not been properly addressed until now.

IREM is a new tool that is useful for decision makers looking for a more balanced distribution between the net socioeconomic benefits and the financial burden stemming from long-term projects affecting multiple (overlapped) generations. In the transport sector, the economic lifespan of major infrastructure projects is very long (20, 30, 40… years), but properly maintained these types of infrastructures may last indefinitely. A well-designed financing formula, besides ensuring the project's financial sustainability, should arguably ensure intergenerational equity. The IREM model offers a way to analyse the impacts on overlapping generations, meaning the various groups of people, centred around a specific year, that will be affected by the project. The people included in a generation will not change very much in relation to the prior or the next one, as not many people enter or leave society in a year, but after many years the component of a generation will be sensibly different (ISR, 2017).

In this model, the gap between the central year of overlapping generations in of one year. Accordingly, *intergenerational redistributive effects* are those occurring between *annual generations*. The main difference between this generational approach and the one used in most scientific papers consists on the meaning of what a generation is[12]. Typical assumptions for the generational concept (and, by extent, the concept of "intergenerational") in macroeconomic models imply a genealogical meaning without a clear definition of its timespan and, on the other hand, genealogical generations essentially do not overlap. A clear definition is also absent in microeconomic studies, and in studies that aim to assess the implicit distribution in the CBA of the intergenerational preferences of society. However, the concept of overlapping annual generations has an *ad-hoc* meaning in IREM, including a central year and a timespan.

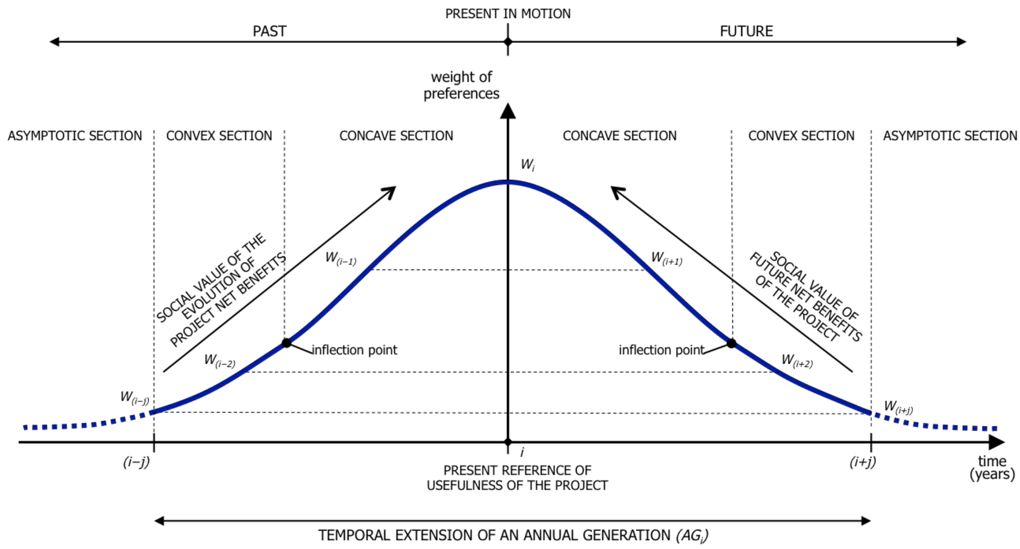
In the IREM, the concept of *annual generation* (AG_i) refers to a generation pivoting around a year, *i*, of the project's lifecycle, which incorporates, besides the "society" of year *i*, those of some previous years and those of some of the successive years. As explained before, the non-central "societies" do not have the same members and those who stay as members of the generation have a decreasing interest the farthest they are from the year in which they are observing the project[13]. This explains the use in the model of a theoretical bell-shaped curve to represent the weighted sum of the utilities of a transport project for the society belonging to any given annual generation (cf. Figure IV-2).

[12] For more details and references see Penyalver & Turró (2017).

[13] It is essentially the same argument that justifies the use of the SDR.

Indeed, considering year *i* as the pivotal moment associated to an annual generation, individuals living in that year can assess the value of the benefits and costs, but only part of the effects occurring in preceding or following years. Moreover, although most individuals in year *i* have already been affected by the project in previous years and they will probably continue to be affected in the future, they are less numerous and subject to more uncertainties as they find themselves farthest from the pivotal year.

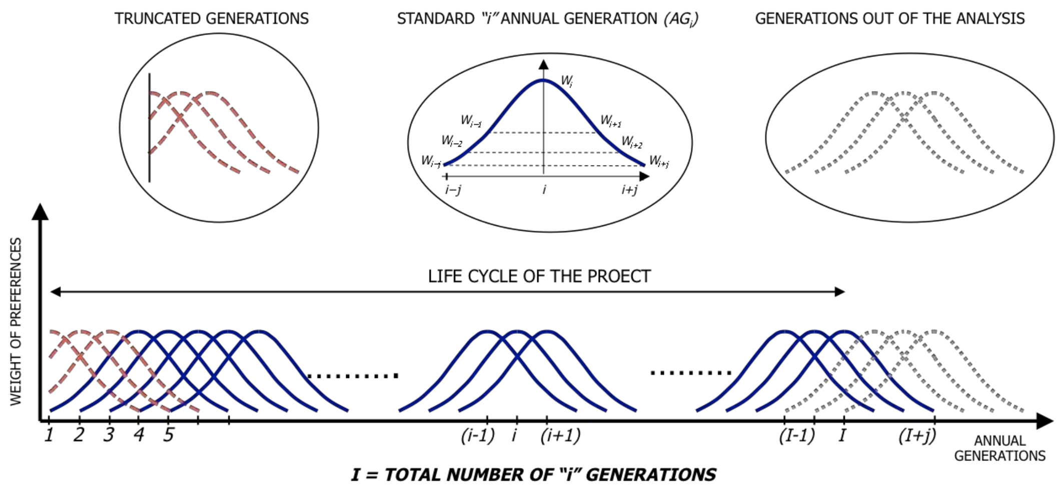
Figure IV-2. Conceptual curve of an annual generation in the IREM model



Source: Penyalver & Turró, 2017

Figure IV-2 shows that the curve function (onwards, the *weighting curve*) for an annual generation keeps the highest utility of transport infrastructure projects in the short-term for society living in the present (central) year in comparison to the long-term. From this pivotal year (*i*), the weighting curve for the years included in the generation slopes down on both sides. Because the economic preferences of the agents in the generation reach, logically, their maximum in the central year.

Figure IV-3. Generational assessment of the inter-annual differences between costs and benefits



Source: Penyalver & Turró, 2017

Taking as time reference the moment of decision to build, the intergenerational impact analysis in IREM is performed from the perspective of a “present in motion” where the investment has not been happened yet. It is assumed that only individuals living in the central years of the future generations affected will really know what finally occurred, so risk perception should be similar for both current decision-makers and future generations concerned by its impacts (cf. Figure IV-3).

Finally, a critical difference of the IREM with other economic approaches is that the function represented by the weighting curve includes, for each year within an annual generation, both past and future project-related effects.

6. ASSESSMENT OF THE POPULATION’S TIME PREFERENCES

A major aspect of the research was to define a theoretical function for the weighting curve in the IREM. Conducting an ad-hoc survey was considered the best way to design a representative function. It was designed with the purpose of determining the importance of major transport infrastructure projects for individuals living in a specific year and how they would appreciate them when they saw them far from the central year in which they were living. In a hypothetical scenario given to respondents, this importance was reduced the further they were placed from the central year of the annual generation. The resulting weighting curve was expected to represent people’s perceptions and preferences related to the relevance of past and future project-related effects in their present welfare.

Survey research is one of the most important sources of gathering data in the applied social sciences (Groves et al., 2009). When survey questions have high reliability, they allow to measure opinions, attitudes and behaviours (Alwin, 2007). Nevertheless, measurement error is an inherent component of survey research, and survey questions are imperfect representations of the concepts they intent to measure (Biemer et al., 2011). In our case, the development of the measurement instrument (questionnaire) was based on current best practices in survey research. In order to minimise measurement error properly, it was followed a *three-step procedure* to design survey questions (Saris & Gallhofer, 2014). In the first step, the concepts to be measured were defined in detail. In the second step, specific statements derived directly from the concepts were developed. In the third step, all the elements that the questions should have were included in the statement; for instance, contextual clues, and, finally, they were transformed into survey items. The first survey item included an introduction with explanations about the hypothetical infrastructure investment and related definitions, the question stem, a numeric response scale and a visual aid for an online survey which included a map pointing out the places affected by the new infrastructure.

The questionnaire was developed with the idea to be administered in an online access panel. Both the infrastructures of reference and the members of the panel were located in Catalonia. Respondents were asked to choose the language of the survey between Catalan and Spanish. It was divided into five blocks and each block had an introduction. In the first block, the survey was presented with a short description of its purpose. The second block described two highway infrastructure projects (the “Eix Transversal” and the “Forth Ring Road”). The third block included questions that represented control variables to detect differences in the profiles of respondents, e.g. questions related to mobility behaviour. The fourth block introduced an explanation to aid the respondent answering questions about their preferences over the transport infrastructure projects. Finally, in the fifth block, the concepts of interest were asked.

The survey was administered through the NetQuest commercial online access panel in February 2016. Participants in the panel are recruited by invitation. As they participate regularly in the panel, their socio-demographic information for quota sampling is already known. The sample for this survey consisted of individuals over 18 years old living in the four provinces of Catalonia (Barcelona, Girona, Lleida and Tarragona). They were randomly selected based on demographic quotas that mirror the characteristics of the population. Upon full completion of the survey, respondents received points that give access to gifts. The total number of completed interviews was 208. The data was analysed to define the time span of an annual generation and to establish the weights for a theoretical weighting curve. Analyses were conducted using R Studio Version 0.99.893 (RStudio Team 2015) user's interface for R statistical environment (@R Version).

The generation concept was incorporated in the survey by means of a question relating both to the respondents' economic behaviour and their perception on how society should repay the investment (onwards, control question). This question confirmed whether respondents understood the concept of generation or not:

> *«Now, imagine that the third lane of the C25 motorway project is open in 2020: Which one of the following groups of people should bear the largest part of the public expenditure that this investment entails?»*

A. *People living in Catalonia when the project's construction starts (before 2020).*
B. *People who will live in Catalonia from 2020 on, after the project is commissioned.*
C. *People living in Catalonia during and after the project's construction.*
D. *People living in Catalonia before, during and after the project's construction.*

In order to estimate the time span of a transport infrastructure investment, the survey presented a vignette describing a hypothetical investment that consisted in adding the third lane in an already existing motorway (Eix Transversal of Catalonia C-25). Respondents were given a detailed description of the project including a map. The project would be implemented from 2016 and would be commissioned in 2020. In this hypothetical situation, respondents were public officers, responsible of deciding which was the most suitable time span to finance the investment (a number from 0 to 100 years). The question, translated into English, was as follows:

> *«For how long, do you think, the Catalan Government should spend public money from its annual budget in this investment?»*

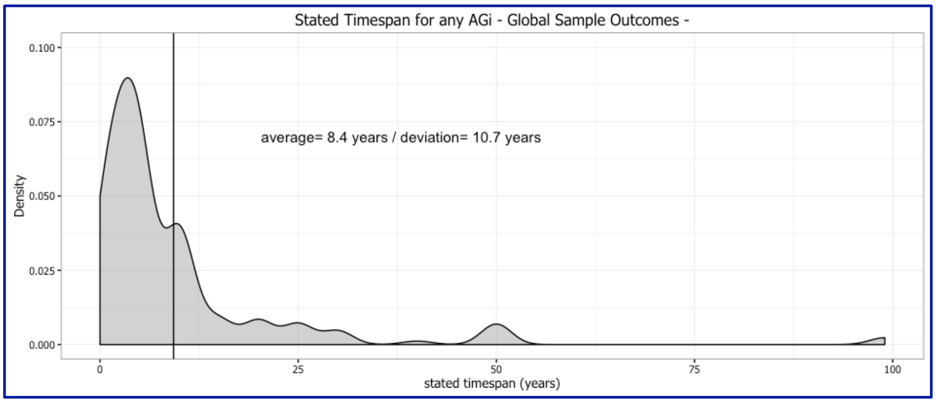
This question was used to establish a time span that allowed estimating the yearly importance weights in the annual generation. Following the results of the survey's pre-test phase, the investment's time span in the questionnaire was fixed in nine-years. Pretesting results indicated that an odd number better reflected a generation centred around the commissioning year of project. It also showed that a generation covering a slightly longer period that the first one proposed (7 years) would be better adapted to represent everyone's perceptions. Next, respondents were asked to imagine they were in 2020. Taking this year as a reference, they rated on a score from 0 to 10 points the importance of the infrastructure project's effects over time, in comparison to the value they assigned to the central year (2020).

The participants in the survey were asked to rate first the central year (2020). Then, they could rate the importance of the project's impact in pairs of years (2019-2021, 2018-2022, 2017-2023 and 2016-2024). This provided them with the stimuli to understand that they could rate the social impact of the project in a different way depending if the year they rated preceded or followed the opening of the motorway extension. The aim of presenting a project that would expand an existing motorway was to make respondents aware that infrastructure investments convey potential social effects and to make them familiar with the rating mechanism. This facilitated the repetition of the exercise presenting a second scenario, a new motorway in the public agenda of Catalonia, the "Forth Ring Road" (B40 motorway) that has been discussed for a very long time. As the IREM is expected to be used in decision-making processes of infrastructure investments, this case presented an illustration of its potential use in a real situation.

Despite following best practices in survey research to develop the survey measures used for this case, answering about hypothetical scenarios may be a difficult task for some respondents. Actually, it should not be excluded the possibility that respondents rated the importance of the project's impact considering their present situation, not a future one. However, research suggests that judging concrete scenarios, even if hypothetical, can be closer to judging real daily life events (Alexander & Becker, 1978; Beck & Opp, 2001). Therefore, by presenting very concrete scenarios, respondents in the survey were able to form an opinion on the subject under investigation. Results presented below show high variability in the data when sub-samples of different socio-demographic characteristics were analysed, being an indication that different profiles of respondents had indeed a different opinion.

The first outcome of the survey data analysis was the estimation of the time span. Figure IV-4 shows that the average value was 8.4 years (sd=10.7), which should be interpreted as the average number of years survey respondents thought an infrastructure should be fully paid in[14]. The long tail indicated a large variability on perceptions about how public money should be managed and spent. By analysing sub-samples of different age cohorts, different cities classified according to their population range, among other indicators, significant differences were found among some sub-groups for both, the average time span and its standard deviation.

Figure IV-4. Density trace of the 'stated timespan' for the global sample



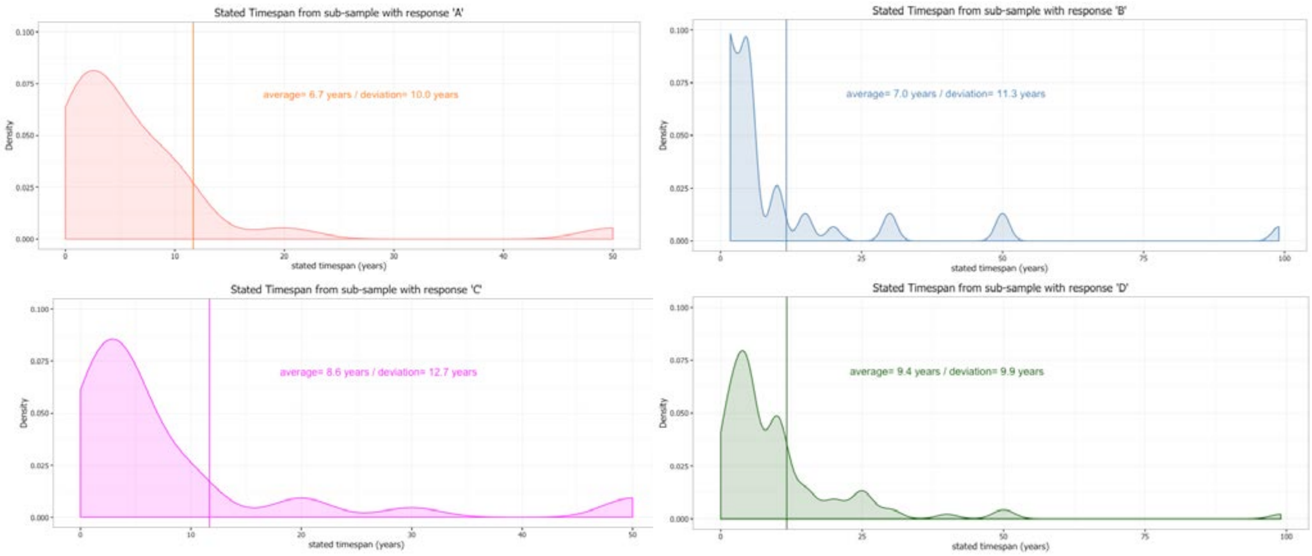
Source: Author

The total sample was divided in four groups (A, B, C and D) corresponding to respondents' answer on whom should bear the project's costs[15]. Within each sub-sample, similar time span values and similar tails for density traces were obtained (Figure IV-5). This indicates that citizens' opinion about public money management differs after controlling for age, sex, place of residence, etcetera.

[14] Two extreme values both with a timespan = 99 years were dropped from the analysis.

[15] According to the options A~D in the survey, respondents had to decide what generations of taxpayers in Catalonia ought to foot the bill of the project: A) taxpayers, during the construction phase; B) taxpayers, from the commissioning of the project onwards; C) taxpayers living in Catalonia during and after the construction phase; D) the same that C) and, in addition, generations of taxpayers living even before the construction phase.

Figure IV-5. Density traces of the 'stated timespan' based on the classification of respondent's opinion



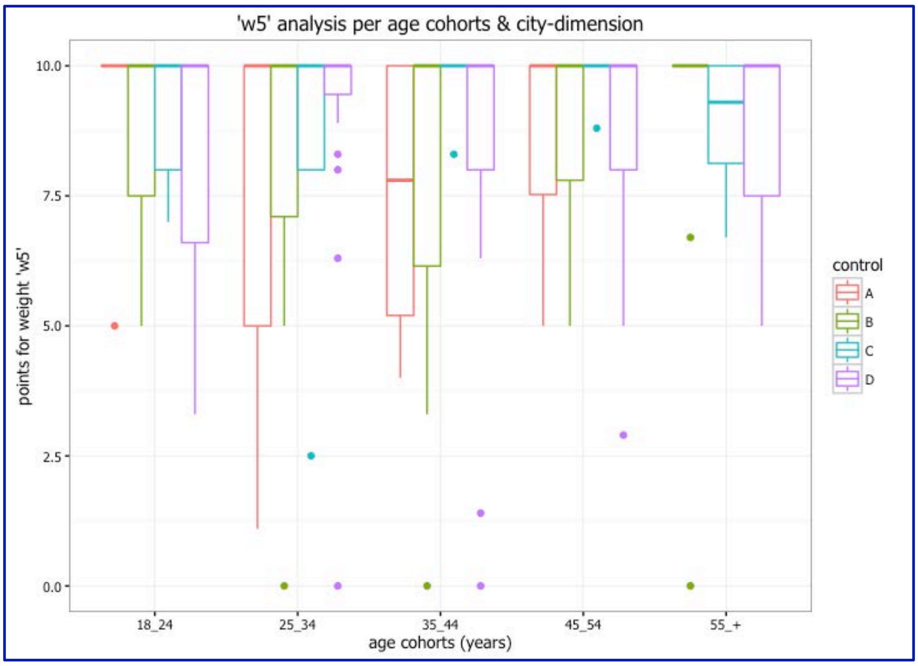
Source: Author

The second part of the survey data analysis aimed at estimating the importance of weights given to each year included in an annual generation, AG_i. As already mentioned, a time span of 9 years was fixed in the questionnaire. Respondents' scores were transformed to obtain values in a standard scale in order to properly compare them. As respondents were asked to rate on a score from 0 to 10 each year within a time span of 9 years, the resulting data allowed comparing respondents' preferences year-on-year within the time span, but it did not allow statistical analysis for the whole sample (because the total amount of points differ for each respondent). Therefore, for each respondent, every set of yearly scorings in the time span was divided by the maximum score given by the same respondent. In all cases, this maximum corresponded to year 5, the central year in the questionnaire's time span. The respondents' answers were kept out when they scored zero at any year in the time span (11.3% respondents in the survey item about the B-40 motorway project). Onwards, the set of the resulting valid outputs was referred as *respondents' adjusted scoring*.

Next, the focus was set on the correlation of the whole set of socio-demographic control variables in the survey with the respondents' adjusted scoring. Particularly, it was found that the "age cohort" and "control question" variables had an important influence in the respondents' scoring. Information about the place of residence, gender, language of the survey, etc. did not show significant differences among classes. Moreover, disaggregating to further levels resulted in very small sub-samples without statistical power.

Once identified the main variables conditioning respondents' outputs, it was possible to disaggregate the sample's yearly scores and to calculate the main statistical indicators in each year within the time span. Figure IV-6 shows a low dispersion in the respondents' adjusted scoring obtained for every age cohort, regardless of their response to the control question ("control" in the Figure's label). A similar pattern was found for all the years in the timespan (cf. Table IV-2).

Figure IV-6. Box chart for the respondents' adjusted scoring in year 5



Source: Author

The yearly average for the adjusted scoring within the time span of 9 years is a reliable indicator of the respondents' preferences for both the B40 and the C25 motorway projects. As shown in Table IV-2, the value of the yearly median and the standard deviation for the average confirmed that the yearly average for the respondents' adjusted scoring represents the collective preferences in the sample.

Table IV-2. Yearly-average for the respondents' adjusted scoring within a timespan of 9 years

TIMESPAN OF 9 YEARS	AVERAGE FOR THE ADJUSTED SCORING								
	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9
Median	6.00	6.70	7.80	8.60	10.0	8.70	8.30	8.55	10.0
Average	**5.62**	**6.22**	**6.90**	**7.54**	**8.61**	**7.72**	**7.41**	**7.00**	**6.68**
Standard deviation	4.06	3.63	3.23	3.01	2.44	2.82	3.03	3.47	3.96
Yearly increment (+) /decrement (−)	---	+0.62	+0.68	+0.64	+1.07	-0.89	-0.31	-0.39	-0.32

Source: Author

By taking into account the trends and patterns represented by the yearly increments or decrements in the importance values, it can be analysed how people's preferences change over time. Our results show that from the year of reference (2020) to the future, respondents' adjusted scoring decreases in the short run. Between the year 5 to 6, this decrement is three times bigger than in the long run (years 6 to 9). For typical discounting models reflecting consumers' preferences it implies that the SDR should decline at a higher rate in the short term that over longer time horizons. This pattern, indicating that consumers' preferences for major transport projects change over time, is actually a major finding of this research because it puts into question a basic hypothesis of the rational choice theory. A second conclusion is that, from the past to the year of reference, the rate of change in the respondents' adjusted scoring increases almost twice at years 4 and 5 (2016 and 2017). This pattern implies that choice behaviour is not very consistent over long time horizons.

Our findings show that when respondents were asked to take decisions that would affect them and the rest of the society they lived in, they still prefer earlier benefits to later ones. The overall pattern of responses confirms that individuals care more about consumption effects in their welfare in the short term (years around the year of reference) than about benefits before or after the reference year. This finding implies that the property of time consistency assumed in discounting models does not hold for preferences about investments in transport infrastructure.

The next step was to determine the most suitable function, $F(t)$, to represent the weighting curve in the IREM within the and the corresponding length of a standard annual generation. The results of the survey suggest that any curve adapted to the IREM's definition of annual generation should have two different branches. The first one increasing from the past to the pivotal year of reference i, and a second one decreasing from this year i to future time units. Most probabilistic functions follow this pattern and many of them are non-symmetrical. They can be defined by three shape parameters (a, b, c): one that determines that the highest value in the curve occurs for the pivotal year of reference (year 5 within the time span of the survey); a second one determines this value (in the pivotal year); and, the third one determines the rate of declining for the curve.

It was estimated the best fitting curve according to the value of the respondents' adjusted scoring for every year and the pattern of increments and decrements described by the survey data. The points representing those values were plotted and taken as benchmarks to validate the probabilistic curve. The theoretical symmetrical features for the curve considered in the IREM (Penyalver & Turró, 2017) were not well adapted to the benchmark intervals resulting from the survey, as can be seen in the chart in Figure IV-7. The gradient for the branch from the past to the central year of reference should be stronger than the gradient from this pivotal year to the future. Therefore, the theoretical model was adjusted empirically in order to adapt it to the best fitting curve, exploring several options, among them a Gaussian, a Gumbel and a Weibull function.

After exploring and rejecting Gaussian and Gumbel probability functions to adjust the weighting curve $F(t)$ linked to a standard generation[16], the Weibull probability function[17] appeared as quite adequate, given the non-symmetrical attenuation of the yearly weights within a non-determined time span and the possibility of adjusting a shorter branch from the past to the pivotal year. To find the best fit for the curve, it was took the central year of reference in the time span in the survey questions (2020), which corresponded to the year with the maximum in the respondents' adjusted scoring. It was assumed that the pattern of mitigation i.e. the weights' yearly attenuation from the pivotal year, could be represented by percentage weights[18], w_j, decreasing through time. For $t>0$, the gradient of the respondents' adjusted scoring represented by the function $F(t)$ declines more strongly in the short term than in the long term. Fitting a Weibull function required imposing the following boundary conditions:

[16] The methodology followed to fit and reject the Gaussian and the Gumbel probability functions is documented in the Appendix attached.

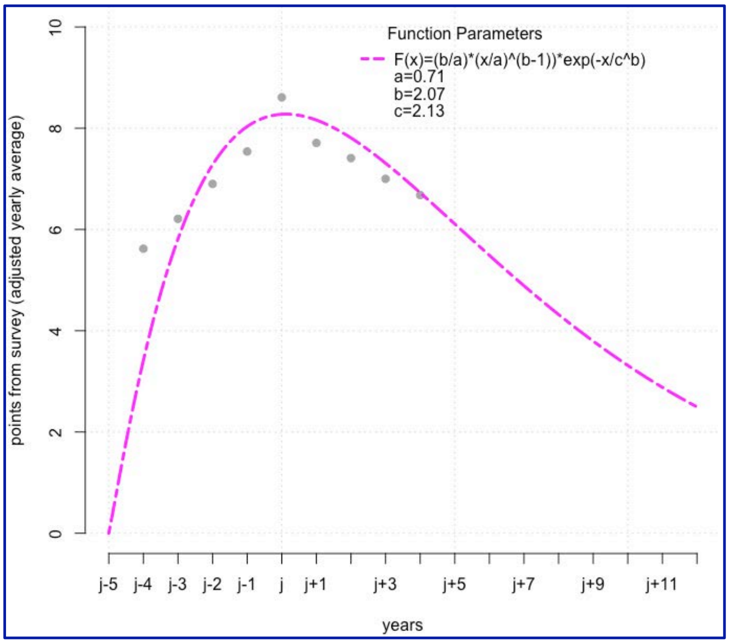
[17] The Weibull function also behaves as a non-exponential rate of decline function when $t>0$, therefore, it will tend to decrease strongly in the short term more than in the long term.

[18] Percentage weights correspond to people's preferences over costs and benefits occurring either before or after the 'pivotal year' of a standard annual generation.

A. The curve reached its maximum at the pivotal year in the time span. According to the empirical data from the survey, this corresponds to year 5.
B. From the pivotal year to the past, at year *j-4* the function's value corresponded to the minimum of the respondent's adjusted scoring. The scoring at year *j-5* should be as close to zero as possible.
C. According to the time span's statistical outcomes (average= 8.4, sd=10.7 years), the future branch would not go beyond year *j+10*.
D. The weighted respondents' adjusted scoring predicted with the parametric function for the year *j-4* was a comparative reference to identify the limit for the time span in the curve from the pivotal year onwards.

Figure IV-7 shows the adjusted curve representing the shape and pattern of the empirical data.

Figure IV-7. Curve fitting from a Weibull function



Source: Author

The equation for the Weibull function obtained from the curve plotted in Figure IV-7 shows that the number of years defining the time span of a standard generation was the range between a scoring equal to 3.4 at year *j-4*, and the year with a similar value to the future of the reference year, *j+10*, (3.3 points), therefore, the time span of the generation was set at 15 years (cf. Table IV-3).

Table IV-3. Predicted yearly-scoring for a 15 years timespan from a Weibull curve

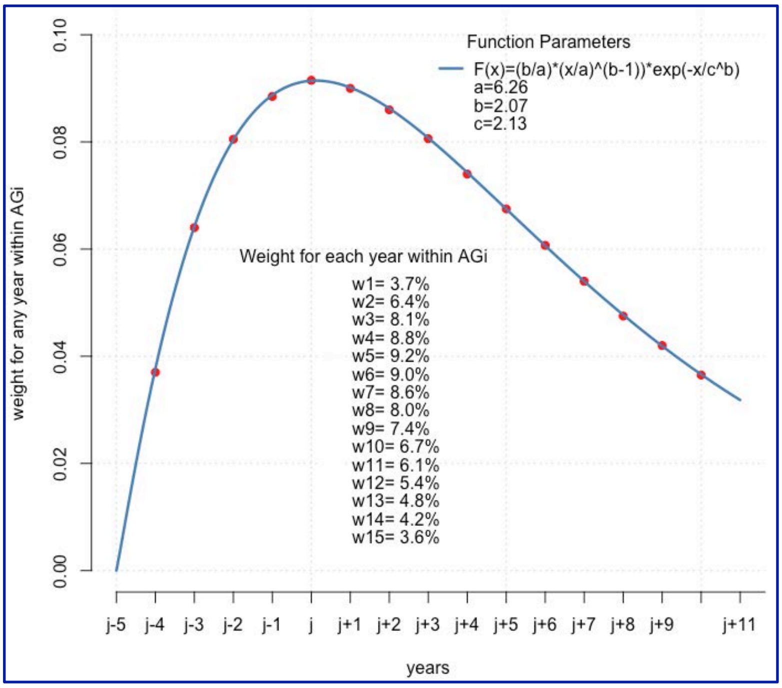
TIMESPAN OF 15 YEARS	ADJUSTED YEARLY AVERAGE OF THE RESPONDENTS' SCORING															TOTAL SCORING
	j-4	*j-3*	*j-2*	*j-1*	*j*	*j+1*	*j+2*	*j+3*	*j+4*	*j+5*	*j+6*	*j+7*	*j+8*	*j+9*	*j+10*	
Scoring*	3.4	5.8	7.3	8.0	8.3	8.2	7.8	7.3	6.7	6.1	5.5	4.9	4.3	3.8	3.3	90.7
Yearly increment (+) /decrement (−)	3.4	2.4	1.5	0.7	0.3	-0.1	-0.4	-0.5	-0.6	-0.6	-0.6	-0.6	-0.6	-0.5	-0.5	---

(*) Values calculated from the parametric function shown in Figure IV-7.

Source: Author

Next, it was determined the scoring corresponding to every year within the aforementioned time span of 15 years and the corresponding year-on-year variation. The predicted yearly scoring at each year within the time span fitted the pattern obtained by the respondents' adjusted scoring in the survey for a 9 years time span. This implies that individuals' preferences in the very short-term, either from the year of reference to the future or to the past are well represented by the gradients of change shown by the curve in Figure IV-7. Next, it was calculated the percentage weights for each year within the AG_i with a simple transformation from the predicted-scorings, finally defining the weighting curve for any standard generation with a 15-year time span (cf. Figure IV-8).

Figure IV-8. Weighting curve for any standard annual generation (AGi) of 15 years



Source: Author

As in the IREM the concept of generation is strictly linked to the individuals affected by the project, and this concept reflects how important a transport project is for the society belonging to a same period of time within the lifecycle of the project (no matter the moment of the analysis), it is fair to concluded that a Weibull weighting curve (imposing the boundary conditions, *A~D*) correctly reflects the weights given by the respondents of the survey to their appreciation of both transport projects. Table IV-4 shows that the non-symmetrical theoretical weighting curve and its parametric function adopted are suitable to reflect how significant the effects of a transport project are for a society's welfare within a standard generation spanning over a 15-year time span.

Table IV-4. Weights in a weighting curve for any annual generation of 15 years

GENERATION	PERCENT YEARLY WEIGHTS (w_j)														
	1	2	3	4	*5	6	7	8	9	10	11	12	13	14	15
Standard (4+11 years)	3.7	6.4	8.1	8.8	9.2	9.0	8.6	8.0	7.4	6.7	6.1	5.4	4.8	4.2	3.6
** Truncated (3+11 years)	-	6.6	8.4	9.1	9.6	9.3	8.9	8.3	7.7	7.0	6.3	5.6	5.0	4.4	3.7
** Truncated (2+11 years)	-	-	9.0	9.8	10.2	10.0	9.6	8.9	8.2	7.5	6.8	6.0	5.3	4.7	4.0
** Truncated (1+11 years)	-	-	-	10.8	11.2	11.0	10.5	9.8	9.0	8.2	7.5	6.6	5.9	5.1	4.4
** Truncated (0+11 years)	-	-	-	-	12.6	12.3	11.8	11.0	10.1	9.2	8.4	7.4	6.6	5.8	4.9

(*) In the weighting curve for the standard annual generation of 15 years the "year of reference" is year 5.

(**) The weights for the truncated annual generations have been calculated by sharing out proportionally the excluded weights among the rest of weights in the corresponding truncated annual generation.

Source: Authors

According to the society being analysed, the values in Table IV-4 cannot be considered as fixed for any IREM application, which should probably be adapted to the society being analysed. The methodology to obtain the relevant values appears, however, as robust and generally applicable. IREM has been applied and is currently being used in a wider research aiming at analysing the intergenerational impact of particular case studies as well as part of a comprehensive methodology to detect white elephants19 in the transport sector.

7. CONCLUSIONS

The paper explains the reasons why a fair decision-making process to invest in major infrastructure projects should consider its real effects on future generations. Whilst exponential discounting and typical SDR are appropriate to estimate the social value of public investments from the perspective of the generation deciding whether or not to carry out the project, they are not neutral to reflect the social interest of projects implying very large timespans. Indeed, the results from this research show that consumers' preferences for major transport projects change as time moves on, which would support the use of declining discount rates (DDRs) to estimate the social value of long-term investments through CBA. This also supports the basic hypothesis of our research line, which states that the present practice to appraise major projects does not take sufficiently into account their impacts on future generations.

The "Intergenerational Redistributive Effects Model" (IREM) model offers a way to incorporate in the decision-making process of a major project its intergenerational impacts. The model provides indicators that compare the net benefits with the real financing burden for overlapping generations, meaning the various groups of people around a specific year, that will be affected by the project. This analysis is complementary to the CBA and provides a view of the fairness of the actual financial payments for the project across the various generations affected.

The first aim of the research presented in this paper was to empirically define the function to be used as a weighting curve in IREM. To determine this function and the timespan of a standard generation required a specific survey with an innovative design in order to place the respondents in a future situation from which they were asked to value the impacts of an infrastructure project in the past and in the next few years. This survey was conducted in Catalonia and in relation to well-known transport projects. The data collected were of good quality and used, in a complex fitting exercise, to establish the timespan for any "standard generation" in 15 years for major investments in transport infrastructure, and to propose the weighting curve shown in Table IV-4 using a Weibull distribution. The values obtained cannot be considered as fixed for any IREM application, which should probably be adapted to the society being analysed. The methodology to obtain the relevant values appears, however, as robust and generally applicable.

The results presented here have been essential for a proper application of the IREM model to several transport infrastructure projects, funded with different mechanisms. The IREM indicators obtained show the strong influence of the project financing models on intergenerational impacts and thus the need to incorporate the financing mechanisms and their implications for future generations into the project appraisal procedures.

[19] This concept is mostly used in relation to public investments representing a severe misallocation of society's resources and, as a consequence, expenditures that can be deemed to reduce the wellbeing of its future members.

8. REFERENCES

- Ainslie, G., 1992. Picoeconomics. New York: Cambridge University Press.
- Alexander, C.S. & Becker, H.J., 1978. The use of vignettes in survey research. Public opinion quarterly, 42(1), pp.93-104.
- Alwin, D.F., 2007. Margins of error: A study of reliability in survey measurement (Vol. 547). John Wiley & Sons.
- Angelsen, A., 1991. Cost-Benefit Analysis, Discounting, and the Environmental Critique: Overloading of the Discount Rate? Report 1991:5. Bergen: Deparment of Social Science and Development Chr. Michelsen Institute.
- Arrow, K.J., 1970. Essays in the theory of risk bearing. Chicago: Markham.
- Arrow, K.J. et al., 1995. Intertemporal equity, discounting and economic efficiency. In al., B.e. Climate change. Cambridge, UK: Cambridge University Press. pp.128-44.
- Arrow, K.J. et al., 2013. Determining Benefits and Costs for Future Generations. Environmental Economics, 341, pp.349-50.
- Arrow, K.J. et al., 2014. Should governments use a declining discount rate in project analysis? Review of Environmental Economics and Policy, 8(2), pp.145-63.
- Arrow, K. et al., 2004. Are we consuming to much? The Journal of Economic Perspectives, 18(3), pp.147-72.
- Arrow, K. & Kurz, M., 1970. Public Investment, The Rate of Return, and Optimal Fiscal Policy. Washington, DC: Resources for the Future.
- Barro, R.J., 1999. Ramsey Meets Laibson in the Neoclassical Growth Model. The Quarterly Journal of Economics, 114(4), pp.1125-52.
- Baumol, W., 1968. On the social rate of discount. The American Economic Review, 58(4), pp.788-802.
- Beck, M. & Opp, K.D., 2001. Der faktorielle Survey und die Messung von Normen. Kölner Zeitschrift für Soziologie und Sozialpsychologie, 53(2), p.283.
- Biemer, P.P., Groves, R.M., Lyberg, .L.E., Mathiowetz, N.A. & Sudman, S., 2011. Measurement errors in surveys (Vol. 173). John Wiley & Sons.
- Bradford, D.F., 1997. On the uses of benefit-cost reasoning in choosing policy towards global climate change. (No. w5920). National Bureau of Economic Research.
- Coleman, J.S. & Fararo, T.J., 1992. Rational Choice Theory Advocacy and Critique. New York: Sage.
- Dasgupta, P., 2007. The Stern Review's economics of climate change. National Institute Economic Review, 199, pp.4-7.
- Eckstein, O., 1961. A survey of the theory of public expenditure criteria. Public finances, needs, sources and utilization. Princenton: Princenton University Press Nacional Bureau of Economic Research.
- EPA, 2016. Discounting Future Benefits and Costs. In U.S.E.P. Agency, ed. Guidelines for Preparing Economic Analyses.
- Evans, D. & Sezer, H., 2004. Social discount rates for six major countries. Applied Economics Letters, 11, pp.557-60.
- Feldstein, M.S., 1964. Time Preference Discount Rate in Cost Benefit Analysis. The Economic Journal, 74(294), pp.360-70.
- Fernández-Baca, 2011. Actualilzación de la Tasa Social de Descuento. Informe Final. Madrid: Dirección General de Programación Multianual del Sector Público del Ministerio de Economía y Finanzas de España.
- Fisher, I., 1930. The Theory of Interest. New York: Macmillan Co.
- Flyvbjerg, B., 2005. Measuring inaccuracy in travel demand forecasting: methodological considerations regarding ramp up and sampling. Transportation Research Part A, 39, pp.522-30.
- Frederick, S., Loewenstein, G. & O'donoghue, T., 2002. Time discounting and time preference: A critical review. Journal of Economic Literature, 40(2), pp.351-401.
- Freeman, M.C. & Groom, B., 2014. Positively Gamma Discounting: Combining the Opinions of Experts on the Social Discount Rate. The Economic Journal, 125(June), pp.1015-24.
- Freeman, M.C., Groom, B., Panapoulou, E. & Pantelidis, T., 2015. Declining discount rates and the Fisher Effect: Inflated past, discounted future? Journal of Environmental Economics and Management, 73, pp.32-49.
- Gatting, A. & Hendricks, L., 2007. Judgmental Discounting and Environmental Risk Perception: Dimensional Similarities, Domain Differences, and Implications for Sustainability. Journal of Social Issues, 63(1), pp.21-39.

- Gollier, C., 2011. Pricing the future: The economics of discounting and sustainable development. Princeton University Press.
- Gollier, C., Koundouri, P. & Pantelidis, T., 2008. Declining discount rates: Economic justifications and implications for long-run policy. Economic Policy, 23, pp.757-95.
- Gollier, C. & Zeckhauser, R., 2003. Collective investment decision making with heterogeneous time preferences. Gollier, Christian, and Richard Zeckhauser. Collective investment decision making with heterogeneous time preferences. No. w9629. National Bureau of Economic Research, (w9629).
- Groom, B., Hepburn, C., Koundouri, P. & Pearce, D., 2005. Declining Discount Rates: The long and the Short of it. Environmental & Resource Economics, 32, pp.445-93.
- Groves, R.M., Mosher, W.D., Lepkowski, J.M. & Kirgis, N.G., 2009. Planning and development of the continuous National Survey of Family Growth. Vital and health statistics. Ser. 1, Programs and collection procedures, 48, pp.1-64.
- Harris, C. & Laibson, D., 2001. Dynamic choices of hyperbolic consumers. Econometrica, 69(4), pp.935-57.
- Harrod, R.F., 1948. Towards a dynamic economics. London: Macmillan & Co.
- Henderson, N. & Bateman, I., 1995. Empirical and public choice evidence for hyperbolic social discount rates and the implications for intergenerational discounting. Environmental and Resource Economics, 5(4), pp.413-23.
- Herrnstein, R.J., 1961. Relative and absolute strength of response as a function of frequency of reinforcement. Journal of the Experimental Analysis of Behaviour, 4, pp.267-72.
- HM Treasury, 2003. The Green Book: appraisal and evaluation in central government: Treasury guidance. Stationery Office.
- ISR, 2017. The Panel Study of Income Dynamics (PSID). A national study of socioeconomics and health over lifetimes and across generations. PSID Main Interview User Manual: Release 2017. Institute for Social Research, University of Michigan.
- Karp, L. & Lee, I.H., 2003. Time-consistent policies. Journal of Economic Theory, 112(2), pp.353-64.
- Kirby, K.N. & Herrnstein, R.J., 1995. Preference Reversals Due to Myopic Discounting of Delayed Reward. Psychological Science, 6(2), pp.83-89.
- Laibson, D., 1997. Golden eggs and hyperbolic discounting. The Quarterly Journal of Economics, 112(2), pp.443-78.
- Laibson, D., 2003. Intertemporal decision-making. London: Nature Publishing Group.
- Lee, J.Y. & Ellingwood, B.R., 2015. Ethical discounting for civil infrastructure decisions extending over multiple generations. Structural Safety , 57, pp.43-52.
- Leleur, S., Salling, K.B. & Jensen, A.V., 2007. Documentation and Validation of the TGB Evaluation model in Greenland. Technical Report prepared for the Home Rule Authorities in Greenland, Centre for Traffic and Transport, Technical University of Denmark.
- Lewis, A., 2001. A Focus Group Study of the Motivations to Invest: "Ethical/Green" and "Ordindary" Investors Compared. Journal of SocioEconomics , 30, pp.331-41.
- Lind, R., 1990. Reassessing the Government's Discount Rate Policy in Light of New Theory and Data in a World Economy with a High Degree of Capital Mobility. Journal of Environmental Economics and Management, 18, pp.S2-S28.
- Lind, R.C., 1995. Intergenerational equity, discounting, and the role of cost-benefit analysis in evaluating global climate policy. Energy Policy, 23(4-5), pp.379-89.
- Little, I.M.D., 2002. A Critique of Welfare Economics. OUP Oxford.
- Loewenstein, G. & Prelec, D., 1992. Anomalies in intertemporal choice: evidence and an interpretation. Quartely Journal of Economics, 107, pp.573-97.
- Lowe, J., 2008. Intergenerational Wealth Transfers and Social Discounting: Supplementary Green Book Guidance. London: HM Treasury.
- Mazur, J.E., 1987. An Adjustement Procedure for Studying Delayed Reinforcement. In Erlbaum, H.N.J.. The Effects of Delayed and Intervening Events on Reinforcement Value. Michael L. Commons, James E. Mazur, John A. Nevin and Howard Rachlin.
- McLachlan, J. & Gardner, J., 2004. A Comparison of Socially Responsible and Conventional Investors. Journal of Business Ethics, 52(1), pp.11-25.
- Meunier, D., Quinet, A. & Quinet, E., 2013. Project apparisal and long term strategic vision. In 41st European Transport Conference. Frankfurt, 2013. Elsevier.

- Moellendorf, D., 2014. The Moral Challenge of Dangerous Climate Change: Values, Poverty and Policy. Cambridge University Press.
- Moore, M. et al., 2004. "Just Give Me a Number!" Practical Values for the Social Discount Rate. Journal of Policy Analysis and Management, 23(4), pp.789-812.
- Newell, R.G. & & Pizer, W.A., 2003. Discounting the distant future: how much do uncertain rates increase valuations? Journal of Environmental Economics and Management, 46(1), pp.52-71.
- Olson, M. & Bailey, M., 1981. Positive Time Preference. Journal of Political Economy, 89(1), pp.1-25.
- Penyalver, D. & Turró, M., 2017. Assessing the Fairness of a Project Financing Formula on Successive Generations. International Journal of Transport Economics, XLIV(1), pp.153-176 (https://doi.org/10.19272/201706701008).
- Pigou, A.C., 1920. Economics of welfare. London: Macmillan.
- Pratt, J.W., 1964. Risk aversion in the small and in the large. Econometrica, pp.122-36.
- Ramsey, F.P., 1928. A mathematical theory of saving. Economic Journal, 38(152), pp.543-59.
- Rawls, 1972. A Theory of Justice. Clarendon Press.
- Roumboutsos, A.B., 2010. Sustainability, Social Discount Rates and the Selection of Project Procurement Method. International Atlantic Economic Society, 16, pp.165-74.
- Samuelson, P.A., 1937. Some Aspects of the Pure Theory of Capital. The Quarterly Journal of Economics, , 5(3), pp.469-96.
- Saris, W.E. & Gallhofer, I.N., 2014. Design, Evaluation and Analysis of Questionnaries for Survey Research (Second Edition). John Wiley & Sons.
- Scott, M.F.G., 1977. The test rate of discount and changes in base-level income in the United Kingdom. Economic Journal, 87, pp.219-41.
- Scott, M.F.G., 1989. A new view of economic growth. Oxford: Clarendon Press.
- Soman, D. et al., 2005. The Psychology of Intertemporal Discounting: Why are Distant Events Valued Differently from Proximal Ones? Marketing Letters, 16(3/4), pp.347-60.
- Souto, G., 2003. El descuento social. Hacienda Pública Española/ Revista de Economía Pública, 165(2).
- Stiglitz, J.E., 2013. The Rate of Discount for Benefit-Cost Analysis and the Theory of the Second Best. Discounting for Time and Risk in Energy Policy, 3, p.151.
- Tinbergen, J., 1956. The optimal rate of saving. Economic Journal, 66, pp.603-09.
- von Hagen, H., Schuknecht, L. & Wolswijk, W., 2011. Government bond risk premiums in the EU revisited: The impact of the fi nancial crisis. European Journal of Political Economy, 27, pp.36-43.
- Weitzman, M.L., 1998. Why the Far-Distant Future Should Be Discounted at Its Lowest Possible Rate. Journal of Environmental Economics and Management, 36, pp.201-08.

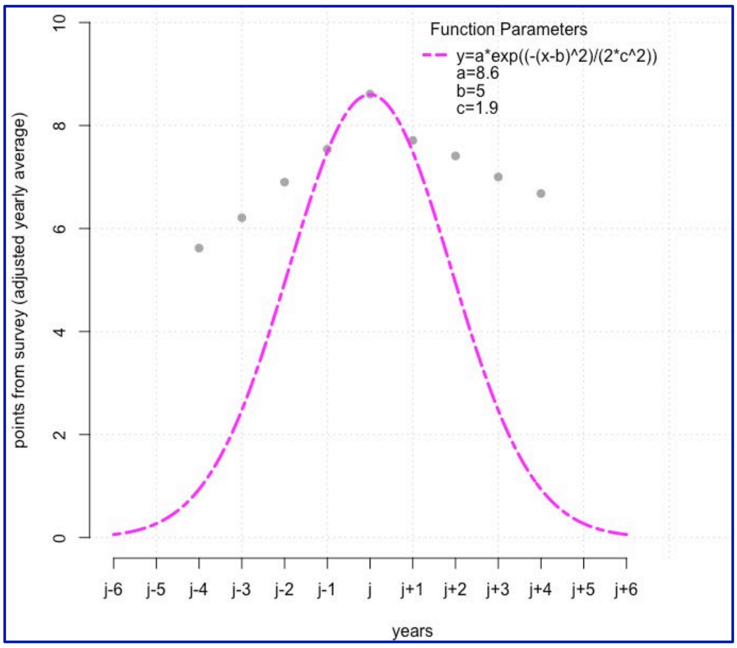
9. APPENDIX A

In order to define $F(t)$, first, it was tested a Gaussian parametric function because it represented our theoretical expectations. A symmetric curve was estimated from a central (pivotal) year declining to both past and future years following the same pattern. To adjust the curve, it was took the central year of reference in the time span in the survey questions (2020), which corresponded to the year with the maximum in the respondents' adjusted scoring. It was assumed that the pattern of mitigation i.e. the weights' yearly attenuation from the pivotal year, could be represented by percentage weights[20], w_j, decreasing through time. For $t>0$, the gradient of the respondents' adjusted scoring represented by the function, $F(t)$, declines more strongly in the short term than in the long term.

It was assumed that the Gaussian parametric function would reach values close to zero at the years outside the time span. Moreover, during the years before year j-4 (j-5, j-6, …) it was assumed that people would be highly unconcerned about the project's early stages, such as planning, design, procurement. Actually, those early stages of investments in transport infrastructures could last several years. Following the same logic, values for years after $j+4$ ($j+5$, $j+6$, …) should be close to zero. During the length of the generation time span, i.e. between the year j-4, and the year $j+4$, values would match the ones obtained in the survey data life span (average= 8.4 years).

The value for parameters a and c, were determined by successive approximations to plot a Gaussian curve of the respondents' adjusted scoring yearly-average from year j-4 to $j+4$. Figure IV-A1 shows the resulting function and the values for its parameters. Grey points represent the respondents' adjusted scoring from the survey data. The plot indicates that a Gaussian function did not adjust correctly the data. Therefore, it was concluded that a Gaussian function does not represent the social preferences for investments in transport infrastructure projects obtained from the data.

Figure IV-A1. Curve fitting from a Gaussian function



Source: Author

[20] Percentage weights correspond to people's preferences over costs and benefits occurring either before or after the 'pivotal year' of a standard annual generation.

As the Gaussian function did not fit the data, a Gumbel[21] function was tested to adjust the weighting curve linked to a standard generation. This allowed testing a non-symmetrical attenuation of the yearly weights within a non-determined time span. Unlike our previous fitting of a Gaussian curve for which a symmetrical curve was aimed at drawing for a pre-defined time span of 9 years, the Gumbel function requires to calculate the parameters for a non-symmetrical probabilistic function with the following boundary conditions (A~D):

A. First, the curve reached its maximum at the pivotal year in the time span, according to the empirical data from the survey this corresponds to year 5.
B. From the pivotal year to the past, at year *j-4*, the function's value corresponded to the minimum of the respondent's adjusted scoring. The scoring at year *j-5*, should be as close to zero as possible.
C. According to the time span's statistical outcomes (average= 8.4, sd=10.7 years), the future branch would not go beyond year, *j+10*.
D. The weighted respondents' adjusted scoring predicted with the parametric function for the year *j-4*, was a comparative reference to identify the limit for the time span in the curve from the pivotal year onwards.

Figure A2 shows the Gumbel curve fitted to estimate the function parameters. To define the time span of a generation using this function the adjusted scoring for the year *j-4*, of 2.4 points, was used. Unlike the Gauss curve, where this value matches the respondents' adjusted scoring in *j+4*, the Gumbel curve conditions outlined above required estimating the adjusted scoring for the years following the pivotal year. It was identified the adjusted scoring in future time observations at *j+7*, (2.3 points) matching its counterpart in past observations at *j-4* (cf. Table IV-A1). Accordingly, the time span was set in 12 years for a Gumbel function; 4 years for the branch from the past to the pivotal year and, 8 from the pivotal year to the future.

Table IV-A1. Predicted yearly-scoring from a Gumbel curve

TIMESPAN OF 12 YEARS	ADJUSTED YEARLY AVERAGE OF THE RESPONDENTS' SCORING											
	j-4	*j-3*	*j-2*	*j-1*	*J*	*j+1*	*j+2*	*j+3*	*j+4*	*j+5*	*j+6*	*j+7*
Scoring*	2.4	4.5	6.6	8.0	8.4	8.0	7.2	6.0	4.9	3.9	3.0	2.3

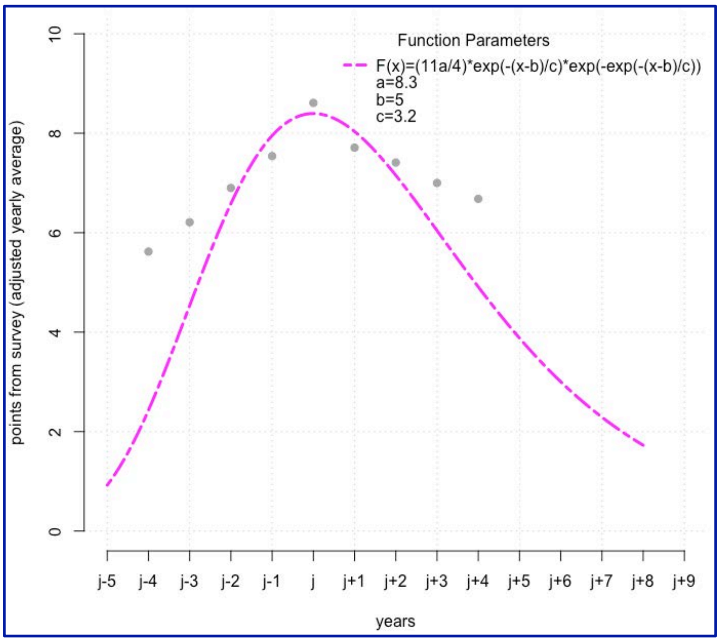
(*) Values calculated from the parametric function shown in Figure A2

Source: Author

As in the case of a Gaussian function, a Gumbel function did not fit to represent the society's preferences for investments in transport infrastructure projects. As it is observed in Figure IV-A2, the Gumbel curve does not match the empirical benchmarks representing the adjusted yearly scoring obtained from the survey data.

[21] Gumbel functions also behaves as a non-exponential rate of decline function when *t>0,* therefore, it will tend to decrease strongly in the short term more than in the long term.

Figure IV-A2. Curve fitting from a Gumbel function



Source: Author

SECTION V. HUNTING WHITE ELEPHANTS ON THE ROAD. A PRACTICAL PROCEDURE TO DETECT HARMFUL PROJECTS OF TRANSPORT INFRASTRUCTURE

Turró, M. & Penyalver, D., 2019

Abstract

The white elephant concept is used to qualify public investments representing a severe misallocation of society's resources or expenditures that can be deemed to reduce the wellbeing of its future members. In the transport sector, white elephants (WEs) are particularly relevant due to the vast amount of resources involved in large-scale infrastructure projects and to their long lifecycle. In most articles on the subject, WEs are major projects showing a certain political or even economic short-term appeal but that are essentially inefficient. In this paper, the definition includes, beyond those that are inefficient, projects that are financially unsustainable and/or very unfair to future generations when properly analysed over their project lifecycle. An early identification as WEs of those efficient projects from the socioeconomic point of view that are bound to entice the failure of a main stakeholder or are unfair to future generations, facilitates reconsidering their financial structuring in order to make them acceptable and avoid the WE label.

The authors propose a new approach to detect *WEs* that goes beyond the traditional detection through standard techniques, such as cost-benefit analysis (CBA), and involves the incorporation in decision-making of new indicators. Those of the *Intergenerational Redistributive Effects Model* (IREM) show the importance of the long-term impacts arising from major investment in transport infrastructure. Using the annuities of the socioeconomic CBA and financial analyses, the IREM indicators allow a look beyond the future impact of the project on society's welfare – measured through conventional CBA– and its capacity of being financed, and produce a good assessment of its intergenerational effects. In this paper, the authors present the results of applying IREM to a set of transport projects in the European Union and, with more detail, to several Spanish motorway projects with private financing. The IREM's outputs indicate that most of the projects in the sample will be fair to future generations. Some of the analysed investments could, however, be considered as WEs when applying the intergenerational perspective. IREM appears therefore to be a useful tool to avoid decision-making mistakes in major infrastructure projects.

1. INTRODUCTION

Decisions about transport infrastructure development are usually based on the general belief that investing in public assets is “productive” for society. In a slightly more sophisticated setting, decision makers require that such public investments be efficient, i.e. expected to generate more socioeconomic benefits than the resources consumed for infrastructure construction and for its operation and maintenance. For investments that can be deemed to reduce the wellbeing of its future members, either because they are inefficient from an economic point of view or because they are financially unsustainable, the label of white elephant (WE) has often been informally used. In this paper, the WE label is also used to identify projects whose redistribution effects can be very unfair when properly analysed over the project lifecycle and therefore, as in the white elephant story, may be ruinous for future generations.

Efficiency is typically evaluated ex-ante through a conventional cost-benefit analysis (CBA) (Thomopoulos et al., 2009; Meunier et al., 2013). In the transport sector, CBA mostly focuses on the analysis of users’ utility, even though costs and benefits are unevenly distributed among the various project stakeholders (Turró, 2004) and investment in infrastructure entails strong impacts of social, environmental and territorial nature over and above user effects (Litman, 1996; Viegas, 2001; Raux et al., 2006; Beyazit, 2011; Trannoy, 2011). The uneven distribution of the project impacts is often pursued by decision makers in order to favour specific social groups or stakeholders (Henisz & Zelner, 2006), whilst non-users impacts, such as climate change agreements, are increasingly taken as the sole justification for certain actions. In some instances, redistribution seems to be the only real argument for certain investments, although this is seldom clearly reflected in the decisional process (Penyalver & Turró, 2018).

Major infrastructure projects systematically involve a strong responsibility for the Government Promoting the Investment (GPI), i.e. the government agency behind the investment. The GPI is therefore expected to engage only in projects that are efficient from the socioeconomic point of view when considering their whole project cycle (Berechman, 2009; Salling & Banister, 2009; Turró, 2015) and ensure that the financing of the project is structured in a way that guarantees that it will not be stopped due to lack of money, at least during the period of its execution and early operation. When financial sustainability is not ensured during this period, a project easily ends up with blockages and consequent cost overruns and delays that unavoidably affect its efficiency. Of course, there is always a great deal of uncertainty on the assumptions adopted in the feasibility analyses and some projects considered convenient ex-ante could become negative for society due to exogenous shocks[1]. However, this is essentially related to the quality of forecasts, a topic falling outside the scope of this paper, which concentrates on the long-term implications of investment decisions based on the best available hypothesis on the consequences of the project at appraisal time.

The possibility of blockages may also come from the opposition of specific sectors/groups or even from the hostility of the bulk of taxpayers. Public investment decisions in general, and for the transport sector in particular, are quite often driven by considerations other than the result of the socioeconomic appraisal (Robinson & Torvik, 2004; Henisz & Zelner, 2006); when this is the case, they are supposed to ensure policy compliance and fairness. On the other hand, even when major investments are deemed efficient from the point of view of the overall society and respond to policy objectives, they may result in unsustainable and/or unfair financial costs for the GPI behind the investment (Hoyos, 2014) and, by extension, for the taxpayer supporting the

[1] The recent financial crisis and other circumstances, such as the impact to a country of becoming a EU member state, which implies a rapid adoption of EU competition policy rules, with strong effects on captive national markets (Veebel et al., 2018), have imply unexpected socioeconomic shocks that have had clear impacts on transport demand forecast.

public promoter. In this sense, it must be observed that, in traditional project appraisal, investment costs are essentially assigned to the first years of the project cycle when the resources are actually consumed. This is reasonable in terms of society's overall wealth (in available resources), but the financial expenditure involved in this consumption is not actually paid during this period, but according to the financing formula adopted. This means that the cash flows that end up covering the financing of the project are generally quite different than the costs and benefits in terms of resources considered in the CBA and depend on the use of loans and other financing mechanisms, which typically postpone the actual payment of the investment.

The financing formula and, in particular, the distribution over the years of the actual payments that concerned users and/or taxpayers will endure, is key to determine if a project that appears as viable according to standard practice can be considered as unfair due to the negative redistribution effects on future generations. It is obvious that future taxpayers and project users cannot react to present decisions. This does not justify, however, that they are treated unjustly. Especially when distant generations will be affected, intergenerational inequality and unfair redistribution may pass unnoticed, but our society is actually becoming increasingly aware, through issues such as climate change and pensions coverage, of the need to incorporate intergenerational fairness into our present decisions.

To measure the effects of the financing formula on the generations concerned during the project lifespan is relatively complex. The *Intergenerational Redistributive Effects Model* or IREM (Penyalver & Turró, 2017) has been designed to analyse these effects comparing the increase in resources generated by the project (net socioeconomic benefits) with the flows of obligations (in terms of actual payments) for the successive overlapping generations affected by the project. IREM indicators may offer valuable insights to identify those projects that would represent a clearly unfair treatment of future generations, in spite of showing an acceptable socioeconomic return for the current society (Penyalver & Turró, 2017). Although it is clear that efficiency should be the main concern of decision makers, the financial implications of certain financing formulae commonly used for the development of major projects of transport infrastructure justify that even efficient projects must show that their financial structuring ensures sustainability and fairness, i.e. that all major participants in the project are able to comply with their expected financial commitments and that future generations are fairly treated.

This paper is organised as follows: The next section offers a review of the literature on both the concept of *white elephants* (WEs) in relation to infrastructure investments and the root causes that may bias the results of conventional feasibility analysis. During this review, a number of arguments on the relevance of the analysis of potential redistribution issues for WEs identification are introduced. Section 3 proposes a comprehensive methodological procedure to hunt WEs. Even if the results of the CBA should be central in normative decision-making to identify WEs (Robinson & Torvik, 2004; Scambary, 2015), a major assumption here is that a step-by-step procedure that incorporates the long-term effects of major projects is necessary to detect WEs and thus to improve the decision-making process. This procedure is actually considered a major contribution of this paper as it encompasses, for first time, both traditional economic approaches and the analysis of redistribution effects, including the intergenerational ones. Section 4 describes the general outlines on how to perform a proper intergenerational impacts analysis with the IREM model. Although the model have been largely presented in other pieces already published, this paper introduces, as a novelty, several details related to financial structuring that are important to correctly run IREM in practice. In addition, it presents an overview of the intergenerational equity patterns obtained from the first systematic application of the model to a relevant sample of (greenfield) projects carried out in the European Union. A more detailed analysis of these intergenerational impacts, based on a case study of three motorway projects in Andalusia (Spain) shows, in Section 5, how IREM can be used to detect

WEs. Section 6 offers general conclusions and recommendations to avoid decision-making mistakes in major infrastructure projects. Finally, Appendix A deepens in some particularities of the IREM model that may be of particular interest to readers.

2. THE SEARCH FOR WHITE ELEPHANTS. A LITERATURE REVIEW

Historically, the concept of white elephant refers to "gifts" that may lead the receiver to bankruptcy and cannot be transferred or sold under normal circumstances (Prasser, 2007; Papanikolaou, 2013; Locatelli et al., 2017). It has been widely used in relation to public investments (somehow "gifts" for the beneficiaries) that represent a severe misallocation of society's resources and have intergenerational consequences (Henisz & Zelner, 2006; Hoyos, 2014; Rius-Ulldemolins et al., 2015; Veebel et al., 2018). For infrastructure investments in particular, this concept refers to projects that have a certain appeal for many people due to their magnitude and "modern" character, are very convenient for potential beneficiaries and may even be apparently affordable but, in practice, entail financial obligations that are too heavy for the citizens receiving the "gift" (Mangan, 2008). Inefficient projects, i.e. projects with a negative net economic present value, which diminish society's economic resources, have often been labelled as WEs (Engel et al., 1997; Robinson & Torvik, 2004; Richard, 2008; Appel, 2012; Wünderich, 2014; Scambary, 2015; Ganuza & Llobet, 2017).

Existing methods for projects appraisal have not been very successful at preventing the presence of WEs in many countries. Available experience indicates that the business cases for public infrastructure often show CBAs and social and environmental impact assessments supporting investment decisions that are unsatisfactory either due to defects of principle or of application (Pickrell, 1990; Richmond, 1998; Williams et al., 2009; Scott et al., 2011; Merrow, 2011). The more typical factors introducing biases in the CBA that may lead to the acceptance of WEs are costs underestimation and optimistic demand forecasts (Flyvbjerg et al., 2002; Flyvbjerg, 2007; Flyvbjerg, 2014). Inefficient projects are harmful for society, but when they end up with important differences between ex-ante financial estimates and real values, something that is rather common, as shown by Flyvbjerg (2007), they can have dramatic consequences on the GPI budget and its capacity to fund other priorities (Ansar et al., 2016).

2.1. DISGUISING THE ELEPHANT. POLITICAL BIASES

Biased CBAs are, in general, supported by political criteria that aim at favouring certain redistribution effects, in particular territorial, social and/or environmental (Turró, 2015). The project itself may be designed to support specific areas (territorial effects) or particular social groups through, for instance, the design of a pricing policy favouring well-identified cohorts within society (social effects). It may also affect in very unbalanced ways some main stakeholders in the project (Turró, 2004). In a major rail investment, for example, the distribution of the burden between the infrastructure manager and the service operators may severely affect its long-term viability. In many projects, the distribution among the different administrations involved (national, regional, local) could also affect the development of the project.

Some elements of the CBA are used, even systematically as in the case of shadow values[2] for labour (DG-Regio, 2015), to positively bias the viability of certain investments following

[2] Shadow values are often used in relation to the reduction of unemployment and poverty and with the promotion of equal opportunities (Harris & Kende-Robb, 2008; World Bank, 2013; Ferreira & Peragine, 2015). For example, the use of workforce wage values lower than the real ones with the aim of supporting labour-intensive projects in

specific objectives. In other cases, it is the use of inappropriate economic values, for instance for travel time savings (Mackie et al., 2001; Fosgerau, 2007; Bang & Banister, 2009), or the inclusion in the CBA of, often unjustified, spillover effects that may generate poor results of the ex-ante appraisal (Martín, 1997; Vickerman, 2007). These biases are typically used to enhance the social effects of the investment during construction (e.g., job creation) and to promote economic development, but may also be used for other objectives that could be important for decision makers but not necessarily good for society's welfare. Politically-driven biases may thus be instrumental in reducing transparency in the CBA methodology and to justify investments that eventually turn out to be WEs.

Equity approaches, which are of major interest for the method presented here, are getting an accrued attention by researchers and planners (Martens, 2006). Particularly in democratic and wealthy societies, the sensitivity to unfair treatment of specific sectors/groups can be expected to hamper those investments that neither address public participation adequately nor incorporate measures to balance unfairness. This is obvious with projects with negative local impacts[3]. If the redistribution effects are strong, they may generate serious opposition from those negatively affected or somehow representing the "mistreated" social groups.

The use of a social discount rate (SDR) to compare the socioeconomic costs and benefits expected to occur over the years represents a strong hypothesis on the willingness of society to renounce to early resource consumption for an accrued amount in the future. On projects unfolding over long timespans the SDR tends to severely reduce the potentially strong effects that may occur in the long-term (Nesticò & Maselli, 2018). The SDR hypothesis which should (ideally) reflect both the social value and the social opportunity cost of project development (Gollier, 2011) is, in any case, adopted from the perspective of the interests of current society, i.e. adopting a clearly "egoistic" view of what the common good is. As the adopted SDR is based, in practice, on a regulated value which may be biased or modified by decision makers, they may end up imposing the use of an "appropriate" value in order to achieve certain legitimate policy objectives (Evans & Sezer, 2004; Leleur et al., 2007; Meunier et al., 2013). This value may respond to the objective of "fairness towards our children", an ecologist mantra that, with the excuse of ethereal benefits in the long run[4], is often used by GPIs to justify extraordinary construction costs. But the fact that low SDRs have the potential to help long-term investments projects to pass the CBA test (Lee & Ellingwood, 2015), does not mean that they are necessarily fair for future generations.

Current procedures for assigning subsidies from upper level administrations (such as Federal Governments, the EU) may also be indirectly supporting WEs. In general, the GPI is expected to demonstrate positive CBA indicators. This represents an incentive to bias the forecasts on costs and benefits in order to obtain grants. Once obtained, the correction of the process to implement the WE becomes extremely difficult and potentially unfeasible. The main point for WEs hunting is that even with grants and subsidies, the financial burden on the GPI, once the higher costs and lower benefits become real, may become unsustainable. In some Member States that are recipients of European funds[5], this mechanism of facilitating the acceptance of WE, besides

regions with high unemployment levels is accepted by the EU (e.g., road projects) and by some International Financial Institutions (IFIs).

[3] The Not-in-my-Backyard (NIMBY) syndrome and the "greens" opposition to transport infrastructure projects are an increasingly serious problem for decision makers.

[4] At the time of the decision to build, it is notoriously difficult to measure the economic benefits of goods without an explicit market, such as reduction of GHG emissions. Moreover, for some transport projects (e.g. high-speed railways) these benefits will materialise several decades after construction.

[5] In particular those stemming from the European Structural and Investment Funds.

entailing a waste of resources, has had the additional undesirable collateral consequence of increasing the public deficit/debt in the recipient country due to the requirement of national matching funds to complement EU grants.

2.2. RUINING FUTURE GENERATIONS

In general, the simple aggregate of discounted total benefits and costs that is presented as CBA results does not offer information about the redistribution of wealth and the long-term implications resulting from the project (Henderson & Bateman, 1995; Litman, 2009). A positive economic net present value (ENPV) essentially suggests that investing is convenient for the society of the moment, as future costs and benefits are discounted to the "present". The idea underlying discounting in CBA is that future resources are less valuable than present ones for the society for which the decision is taken and that citizens are the same over the years. As a result, the CBA implicitly assumes that the project is generationally neutral, i.e. its effects are considered affecting the same cohort of people, which would extend across the project cycle, even if infrastructure projects unfolds over large time spans. However, the dynamics of society imply an evolution of the members of the different generations (ISR, 2017). Although the socioeconomic CBA assigns both costs and benefits to the year when the consumption and generation of resources occur, the positive effects of the project are indeed mostly perceived by individuals belonging to the society of the year in question, i.e. the users and, generally, the society "of each moment", which can be grouped as a generation[6]. Obviously, a generation, even if assigned to its central year (referred here as "annual generation), must cover a set of individuals who were living before this year and will be alive afterwards. A proper way to define such annual generations, which are logically overlapping, has been proposed (see point 4).

Projects that are not delivering, to the overlapping generations concerned, a fair relation between the net benefits and the financial burden could be considered as unfair from an intergenerational perspective. To easily understand the concept, take as an example, an investment funded by the GPI through a "bullet" loan[7]. Under such a funding mechanism, taxpayers of a few specific years –distant from the period in which the decision is taken– end up bearing the responsibility for the full repayment of the principal of the loan, whilst project benefits are similarly split among all the overlapping generations of the project lifecycle. There are strong arguments in favour of including the analysis of fairness in the decision making process for long-term investments (Groom et al., 2005; Lee & Ellingwood, 2015). It is in this sense that decision makers are expected to measure not only the global gains and losses but who benefits and who-and-when bears the costs in order to be able to say whether a policy, integrated investment programme or project is good or bad for society (Bradford, 1997; Ascher & Krupp, 2010). Intergenerational fairness is especially relevant in the case of major investments in transport infrastructure due to the risks and the high opportunity costs that these projects entail for individuals that are young today or even unborn but that may end up bearing much of the negative consequences of potential WEs. This is the main reason why it is proposed to use the IREM model to deal with this critical issue in the detection of WEs. Although a different approach or a more elaborated version of the model may be developed in the future, it is considered that IREM represents a major step in the assessment of intergenerational effects.

[6] Since Mannheim's "The problem of generations" (1923), the concept of "generation" or "social generation" has been used in the sense of "cohort", which refers to people within a delineated population who experience the same significant event within a given period of time (Pilcher, 1994).

[7] It is a loan where the repayment of the entire principal, sometimes even the principal and interest, is due at the end of the loan term.

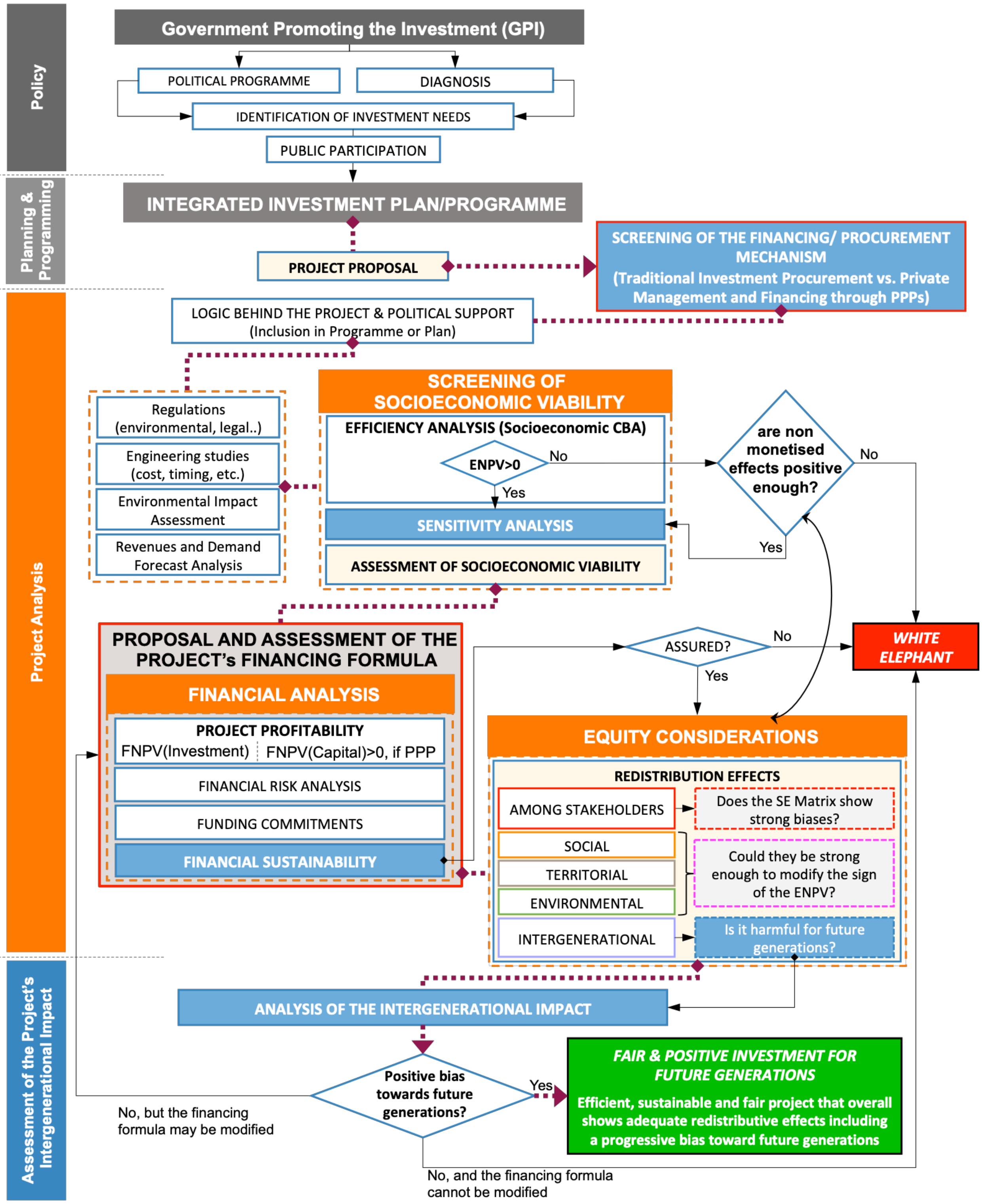
3. METHODOLOGICAL PROPOSAL

Figure V-1 indicates the critical blocks of the proposed method for white elephant “hunting”. This method could be deemed to be similar to standard project appraisal procedures. The difference is that it is both more explicit regarding non-CBA aspects than most procedures to be found in manuals and guides (Engel et al., 1997; Robinson & Torvik, 2004; Scambary, 2015) and that the focus on financial aspects and, in particular, on their implications for future generations of users and taxpayers is considered essential. The ultimate goal of the Figure V-1 scheme is to represent a generic process of proposal, analysis and selection of investment programmes/major projects of transport infrastructure that, if properly followed, can be useful to establish whether an investment should be labelled as efficient, financially sustainable and fair or whether, otherwise, it should be considered a WE. The scheme is mostly applicable to public funding. In the case of PPP arrangements, there is a greater complexity in the procurement and financing mechanisms requiring a greater detail in some parts of this scheme. The intergenerational implications of private participation in transport infrastructure procurement have been analysed in Penyalver et al., 2019.

In order to proceed to the assessment of the project, the analyst should, first, gather sufficient insights of the project’s viability by means of a cost-benefit analysis. A major project should agree with a rational plan or investment programme to ensure that it is framed in an integrated decision process and counts on sufficient political support. The fulfilment of regulations, notably on environmental matters, is also a requirement for the project’s positive performance in the long-term and must be checked as part of the appraisal procedure. While there is not always a solid justification for some environmental regulations, it must be recognised that they are usually aligned with the concern for the wellbeing of future generations, which is a major point in our definition of WEs.

As a second phase, it is necessary to carry out a basic screening process of the feasibility studies, which should include a CBA clearly defining the do-minimum situation and the options that deserve consideration. The analyst should also obtain sufficient information about the financing/procurement mechanism foreseen for the project. This mechanism, particularly when it is not a pure public sector financing, should also be considered an option to be analysed and compared on the basis of efficiency and efficacy objectives, with standard procurement options, in line with the democratic mandate of the GPI. In addition, a thorough analysis of the governance system is essential to prevent the risk of the project not performing as foreseen. A proper legal and administrative framework allowing the necessary flexibility to adapt the implementation process to changing circumstances and a professional and objective-driven management are essential to avoid the delays and cost overruns that could convert a potentially efficient project into a WE.

Figure V-1. Flow chart of the WEs hunting methodology



*Note: Red dashed arrows highlight the main flow of the process, which should positively lead the government promoting the investment to obtain the *"fair & positive"* label for the project. Black arrows indicate secondary processes that may result or not in the *"white elephant"* label

Source: Author

The third stage of the WE hunting procedure must ensure the socioeconomic viability of the target investment. A properly executed CBA is essential to avoid investing in WEs because socioeconomic efficiency is the critical factor in defining the interest of a project for society. The importance of avoiding biases in the elaboration of the CBA has already been stressed. As CBA has many subjective aspects (for instance, in the values for travel time savings, often critical in transport projects) (Lave, 1996), the results of the CBA must always be questioned. They should be positive but also show their robustness through ad-hoc scenario and sensitivity analyses (DG-Regio, 2015), in particular of the questionable variables or parameters (De Palma et al., 2012). Projects showing a low economic rate of return (ERR) are strong candidates to be labelled WEs, particularly if the sensitivity analysis indicates a high probability of obtaining even poorer results. To avoid the WE label at this stage of the procedure, the positive and non-monetised effects of the project that have not been taken into account in the CBA must be valuable enough for society to compensate the high risk of the project ending up with a negative ENPV. In this sense, the conclusions of studies on the potential social, territorial and/or environmental redistributive effects stemming from the project may be used to support decisions for investments with low ERR (Penyalver & Turró, 2018).

There are, nevertheless, some other factors that could justify that projects with negative ENPV become socially acceptable and may, therefore, avoid being labelled as WEs. As the CBA takes only into account the effects of the project that can be measured and monetised to reflect their value for society as a whole, those that are not included in the CBA, in particular some positive externalities, may justify the execution of projects that do not show adequate profitability. On the other hand, there is also the possibility that non-monetised negative effects appear strong enough to question the viability of a project with positive ENPV. In a proper decision-making process, these effects, not included in the CBA (not even through shadow values or similar) should be somehow compared with the ENPV value to check their potential to alter the consideration of the project as viable or not and, as a consequence, if they deserve the WE label.

As a fourth stage, if the project passes the CBA screening, the analyst should assess the financial viability of the project according to the financing mechanism adopted. The conventional and intuitive approach to analyse project efficiency through CBA is also commonly used for financial risks analysis (Raftery, 2003). The GPI may opt for purely public financing, the traditional model for most transport investments, or find alternatives, either through a public company (as it is the case in many rail projects) or a PPP. The financial proposal must ensure that, under the adopted hypothesis and reasonable variations, no main stakeholder may be unable to comply with its financial commitments (DG-Regio, 2015). This means that the GPI should demonstrate that the project will generate enough revenues to allow a proper long-term financing of the investment (a responsibility that could be assigned to the private partner in PPP) and/or that there would be, in principle, sufficient budget allocations to pay for the annuities (direct payments and loan amortisations) that the GPI is expected to cover when, as is often the case in transport projects, user payments will be insufficient. When, for some reason, budget allocations cannot materialise or the private partner is unable to cover its financial commitments, project implementation will be delayed and, as a consequence, cost overruns will appear. This might easily mean that the profitability expectations plunge and that the project may eventually become a WE.

The firth stage consists of the identification of redistribution issues as, by definition, they are not included in the CBA. The quantification of the redistributive effects from the project on the various agents involved through the Stakeholders/Effects (S/E) Matrix (Turró, 2004) may offer valuable insights on political and social connotations that are critical for the investment viability. Besides the differential impacts on stakeholders, those of territorial, social and environmental nature should also be identified. These effects, usually difficult to quantify and monetise, must be compared with the ENPV. Having a clear money reference to compare with, should allow, at least, some reasonable discussions about the feasibility of the project. However, it is worth noting that some of the most credited redistribution effects (regional development, social integration and similar) will only be observable in the long run[8]; in this sense, it can be pointed out that, beyond the social policy being pursued, they show, in general, a positive bias towards future generations. In line with this point of particular interest for the detection of WEs, which are precisely characterised by their capacity to end up ruining their theoretical beneficiaries, the hunting methodology puts a special focus on the intergenerational effects of major investments because they cannot be incorporated in current CBA procedures.

Finally, there is a last factor to be used to recognise that the "elephant" will be endangering the wealth of its owner through its long-term impacts. Major investments in transport infrastructure will affect many overlapping generations due to their magnitude and their long lifecycle, so costs (in terms of actual payments) and benefits should be balanced to avoid future generations to unfairly pay for the profligacy of current decision-makers, as in the white elephant story.

The actual money payments for the investment are defined by the financing formula adopted. Such payments and those related to the operation and maintenance of the transport infrastructure are ultimately made by users, through direct payments such as tolls, and/or by taxpayers feeding the public budgets contributing to the project. Therefore, the redistribution effects among users and/or taxpayers of different generations are relevant to hunt WEs, while the payments between the government agency (GPI) and private actors and ultimately the redistribution effects between private actors and between these and public administrations as a result of a particular fiscal policy unrelated to the project do not fall within the scope of the intergenerational analysis, because they are only transfers occurring within specific years. The eventual redistribution effects among the different project stakeholders may raise during the project cycle could be analysed through the S/E Matrix (Turró, 2004).

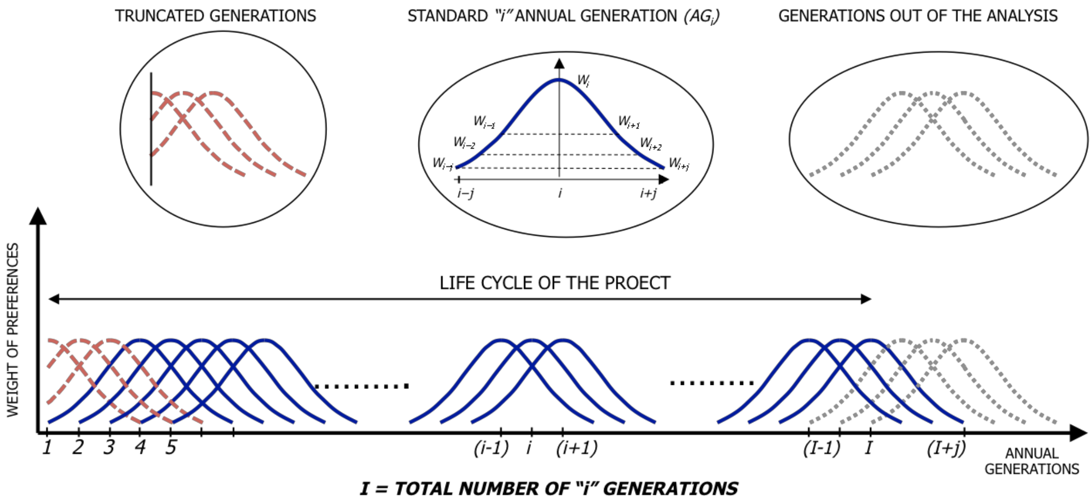
The case of intergenerational redistributive effects diverges from the other redistributive effects because, by definition, future generations cannot participate in the decision. It is, however, the capacity of users and/or taxpayers to comply with future commitments what establishes whether an investment should be labelled as a WE or, on the contrary, the project has to be deemed to be efficient, financially sustainable and fair from an intergenerational perspective.

4. ANALYSIS OF THE INTERGENERATIONAL EFFECTS. AN OVERVIEW

Decision makers usually determine the final financing formula of a project, within the envisaged financing/procurement mechanism, after the decision to build has been adopted. This formula should, in theory, follow a positive conclusion on its efficiency and its financial sustainability. It should also consider the redistribution effects generated by the project. Some of these effects are relatively easy to measure, but there is a lack of metrics to determine whether the funding burden is adequately shared among the various generations affected by the project. This deficiency can be observed in the investment reports of public entities, which disclose very little about this issue (Kotlikoff, 1992; Auerbach et al., 1994; McCrae & Aiken, 2000; Williamson & Rhodes, 2011). IREM has been developed with the objective to cover this gap in the relevant literature and provides indicators on the intergenerational redistributive effects arising from major investment in transport infrastructure. These effects, which are linked to the financing model, are estimated comparing the increase in resources obtained from the investment with the financial charges to users and taxpayers. This is done for each one of the overlapping *"annual generations"* in the project lifecycle (cf. Figure V-2).

[8] Some effects may be included in the CBA through induced traffic over time, for instance, but they are not identified as separate beneficiaries.

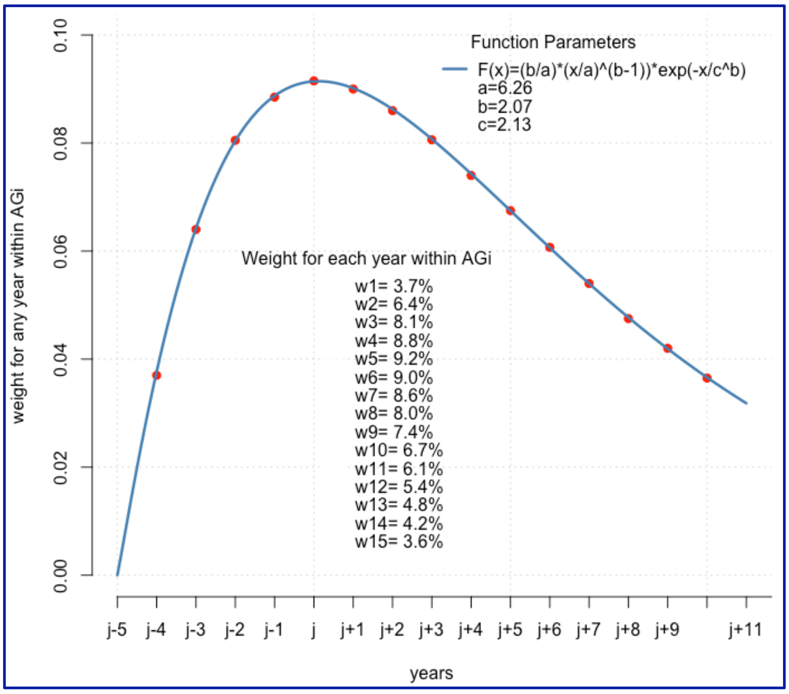
Figure V-2. Scheme showing the weight given to the different years of the overlapping generations



Source: Penyalver D. & Turró M., 2017.

The concept of *annual generation* (AG_i) refers to the population pivoting around a year, *i*, of the project's lifecycle and incorporates, besides the individuals living in year *i*, a percentage of those living in the few years before and after the year of reference (Penyalver & Turró, 2017). The function that defines both the timespan and the weighting curve for the "lateral" years that is used to make the relevant calculations for the standard annual generation in IREM is shown in Figure V-3. This function reflects how significant the socioeconomic costs and benefits, but also the financing effects, stemming from an investment in transport infrastructure are for the individuals (users and/or taxpayers) of an annual generation (Penyalver et al., 2018).

Figure V-3. Function used to represent a standard annual generation in IREM



Source: Penyalver et al., 2018.

As already mentioned, the objective of IREM is to compare the net socioeconomic benefits after commissioning, indicated by the CBA annuities, with the actual payment schedule stemming from the project's financing formula affecting both taxpayers and users. This is done for every annual generation using the relevant weights for the various years included in it. Investment costs are not included in the net benefits calculation because IREM refers to the difference between the resources generated and consumed annually by the project after commissioning, when it starts generating net benefits. These are compared with the actual payments to be made to cover the investment costs. Some of them may be provided by the GPI budgets of the construction years, so they will be confronted with zero benefits on these years, but most projects are financed through loans or other financial mechanisms postponing payments. The net financing amount of the year (amortisation and interest of public loans for public projects or the amount paid by users and the eventual public contributions when privately managed) is then used to calculate the amount contributed by the annual generation. The model thus provides a single value, the gap *(GAP_i)* of the project (net benefits minus financial burden) for each *"annual generation"* using different weights for the various years in the generation (cf. Table V-1).

Table V-1. Weights in the weighting curve for a standard annual generation

STANDARD ANNUAL GENERATION	PERCENT YEARLY WEIGHTS (w_j)														
	1	2	3	4	*5	6	7	8	9	10	11	12	13	14	15
Timespan = 15 years	3.7	6.4	8.1	8.8	9.2	9.0	8.6	8.0	7.4	6.7	6.1	5.4	4.8	4.2	3.6

(*) In the weighting curve for the standard annual generation of 15 years the "year of reference" is year 5

Source: adapted from Penyalver et al., 2018.

The time series of the intergenerational gaps is made from a common baseline to offer a clear picture of the evolution over time of the project's effects on the concerned generations and is used to calculate the different IREM indicators. The average of the different generational gaps obtained along the project lifespan *($\overline{GAP}$)* indicates whether the project net benefits to be obtained by the successive generations concerned are globally higher than the concomitant financial burden. It is thus a valuable metric on the utility of the investment from the perspective of the future users and/or taxpayers (Penyalver et al., 2019).

The other IREM indicators obtained from the time series allow the assessment of the project's effects on three interlinked dimensions (cf. Table V-2) showing: (1) if certain generations are paying (or expected to pay) more than the net benefits they receive; (2) whether present or future generations will be favoured and the strength of this trend; and (3) whether particular generations will end up being greatly benefited/harmed due to the financing model. These indicators are particularly suitable for large-scale transport infrastructure projects, as they require great amounts of economic resources during long periods of time for their construction and, after commissioning, they still need both significant expenditure in yearly maintenance and operation and in periodical heavy-maintenance to ensure performance continuity. Due to their size and complexity, GPIs use a wide range of management systems and financing structures to implement these projects. Depending on the adopted financial model, users and citizens belonging to generations that theoretically will benefit from the project may be charged, through direct payments and taxes, quite differently. The indicators can help selecting a financial structure that distributes the financial burden in a way that does not represent unfairness[9] to the generations to come and avoid the project to be labelled as a WE (cf. Table V-3).

[9] Overall, the "fair/unfair" concept refers to moral obligations towards future generations (Rawls, 1972).

Table V-2. Analysis of intergenerational impacts: dimensions and general outlines of IREM outputs

Dimensions of the analysis of intergenerational impacts	IREM indicators	Assessment of IREM outputs
D1. Intergenerational Utility The project's financing formula finally adopted by the government promoting the investment should sustain the welfare of future individuals. This implies positive gaps between net benefits and financial payments (by users and/or taxpayers) for the sets of affected individuals (grouped in annual generations) over the project lifecycle.	$\overline{GAP}$: Average value of the different generational gaps *(GAP_i)* obtained along the project lifespan, expressed in millions of euros (M€) *GUI:* The *General Unfairness Indicator ($0 \leq GUI \leq 100\%$)* reflects the intergenerational utility of the project. It represents the rate (%) of overlapped generations enduring financial payments higher than the increase of resources obtained from the project	A $\overline{GAP} < 0$ essentially suggests that the project's financing formula has a negative impact for most of the generations affected. Low values for *GUI* indicate that the number of annual generations being unfairly treated (paying more than the net benefits they obtain) is small.
D2. Intergenerational Performance The evolution over time of the effects of the project on the concerned annual generations.	*T&S:* Trend and Slope (in grades) of the time series of the generational gaps of the projects. *($-100g \leq T\&S \leq +100g$)*	*T&S>0* means that the value of the successive gaps tends to be more positive or less negative. The higher the value of this indicator the more useful (or less harmful) the project is for future individuals.
D3. Intergenerational Redistribution In projects unfolding over large timespans, redistribution issues may arise if there are significant transfers of the project's financial burden among groups of annual generations.	*IRESI*: The *Intergenerational Redistributive Effects Sharing Index* informs about how redistribution effects are shared among generations over time *($0 \leq IRESI \leq 1.00$)*	*IRESI* tends to 1.00 if the differences between the value of the positive and the negative generational gaps are important, which means that the financing formula is severely biased in favour of certain generations.

Source: Author

Projects with $\overline{GAP} > 0$ typically show a positive performance (T&S >0) and thus they must be considered positive for future generations. In this case the project's label must be "fair-balanced". A negative T&S is also possible in combination with a low GUI, which typically implies that $\overline{GAP} > 0$, meaning that the annual generations involved will have lower (positive) GAP_i as years go on. In any case, if $\overline{GAP} > 0$ and GUI is low, the project's intergenerational impact should be considered positive but unbalanced, as only a few overlapped generations may end up with net benefits lower than the concomitant financial impact. In this case the project must be labelled as "fair-unbalanced".

Table V-3. Different cases for the combination of IREM's outputs (Project Intergenerational Rating Scale)

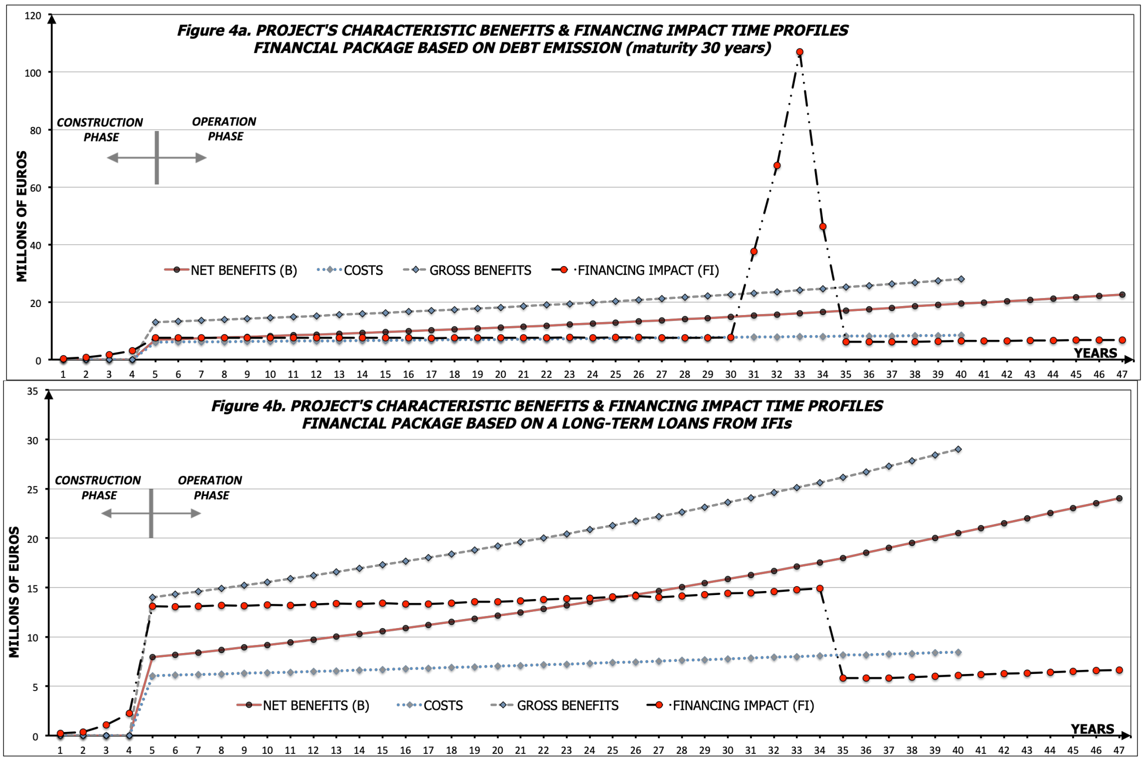
D1. Utility		D2. Performance	D3. Redistribution	Project intergenerational impact	Project Label	
$\overline{GAP}$	*GUI*	T&S	*IRESI*			
> 0	≈ 0	> 0	≈ 0	Positive	*Fair-balanced*	*BAL*
> 0	Low	> 0	Any	Positive but unbalanced	*Fair-unbalanced*	*UNB*
> 0	High	> 0	Low	Positive but unfair	*Unfair +*	*UF+*
≈ 0	High	Any	High	Poor and very unfair (*)	*Very* unfair	*VUF*
≤ 0	High	< 0	Any	Negative (*)	Regressive	*RGS*

(*) Transport infrastructure projects candidates to be labelled as *white elephants*

Source: Author

Projects with high *GUI* may be complex to label if they show a positive intergenerational performance. In these situations, the analyst should first look closely at the value of the $\overline{GAP}$: If GUI is high but $\overline{GAP} > 0$ (many generations paying more than the perceived benefits with most negative gaps being small), *T&S* is positive and redistribution effects can be disregarded (IRESI ≈ 0), the project's intergenerational impact must be considered positive but unfair (*"unfair+"* label). But if GUI is high and the generations having negative gaps lead to a $\overline{GAP} \approx 0$, the project's intergenerational utility is poor besides unfair. In these situations, the project might be considered as (strongly) positive just for a few annual generations and, therefore, should be labelled as "very unfair" overall ("VUF" label). Actually, depending on the value of the GUI and the strength of the T&S, a project with modest redistribution effects could even be considered as a white elephant. This is obviously the case of projects with $\overline{GAP} < 0$ (usually concomitant with a high GUI) with a negative T&S, which leads to label such projects as "regressive", as the financial burden is increasingly higher than the expected socioeconomic net benefits for the annual generations within the project lifecycle. In this case, the intergenerational impact must be considered absolutely negative and the project should be labelled as a WE.

Figure V-4. Socioeconomic and financial time-profiles of the example (different vertical scales)

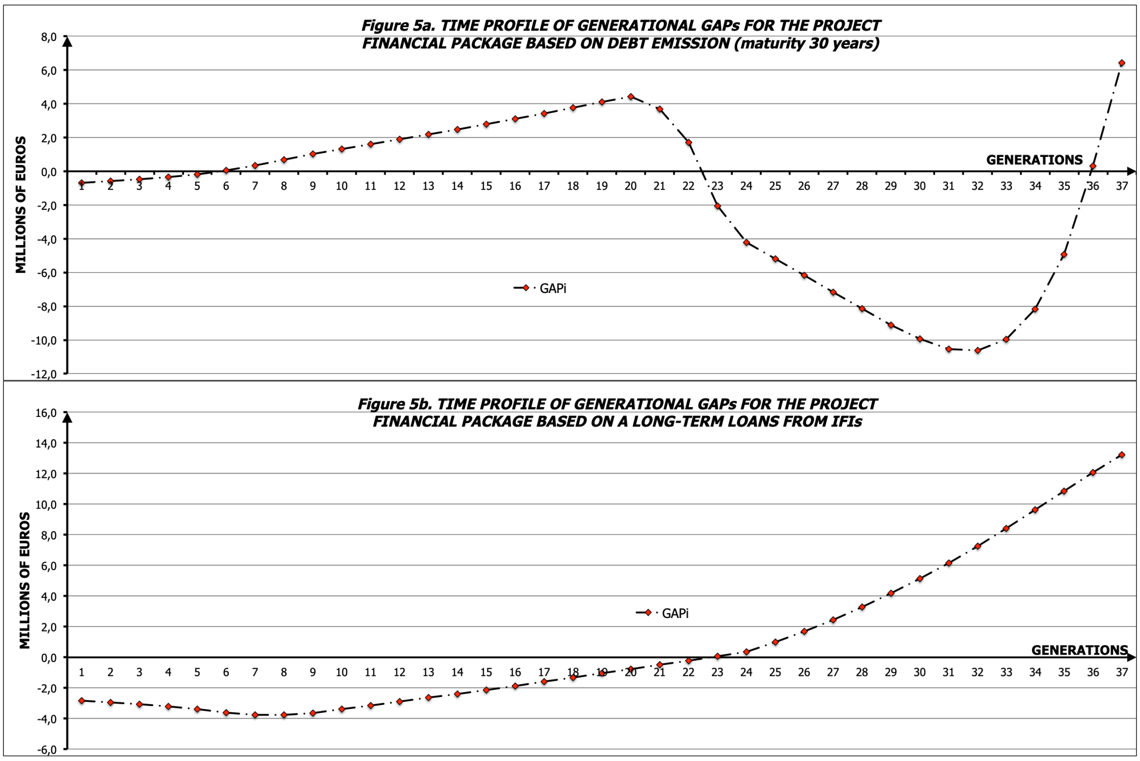


Source: Author

IREM is thus useful to establish to what extend the project's impact is positive for society from a broader perspective than the traditional CBA, as it introduces a comparison between what the individuals affected by the project get as benefits and what they actually pay as users and taxpayers. Whilst benefits are somehow inherent to the project design, payments depend on the financial structure chosen by the GPI to finance the infrastructure. Therefore, in the case of a negative label, the GPI has the chance to increase (to a certain extent) the project's intergenerational fairness by altering the structure of the project's financial package. The actual distribution of yearly charges may be redesigned to better follow the time distribution of the project net benefits and ensure that the project's $\overline{GAP}$ is positive. An example on the potential of the financing formula to align actual payments to the project's socioeconomic benefits is shown next.

Figure V-4 is a graphic representation of the characteristic time-profiles of socioeconomic net benefits *(B)* and financing impact *(FI)* of a simulated transport project for two alternative financial scenarios: Figure 4a shows the time-profiles of a 40 years project cycle (with 4 construction years) financed through funds obtained from project bonds or public debt emissions[10] with 30 years maturity. The reimbursement of the funds is made starting at year 31, according to the capital consumed during the construction period. Figure 4b shows the time-profile of the project financed through soft loans[11] to be repaid during 30 years, with a grace period of 4 years. The IREM model compares the cash flows from the financial analysis with the flows of socioeconomic net benefits, thus their values are in constant terms (removing inflation, in the example estimated at 2%, from the actual financial flows).

Figure V-5. Time profile of the generational gaps of the project



Source: Author

As can be observed, financing through a bond or a debt emission with long-term maturity is equal to transfer the investment financing problem to individuals living in a distant future. In this scenario, early generations obtain net benefits from the project whilst bearing a (relatively) small financial burden (debt interests and O&M costs). However, the rest of the concerned generations endure actual payments that are higher than their net benefits (cf. Figure 5a). If the project is financed through soft loans from IFIs, the investment impact is distributed over the many generations who must repay them. In the example, this results in a more balanced redistribution among the generations affected during the project lifecycle (cf. Figure 5b).

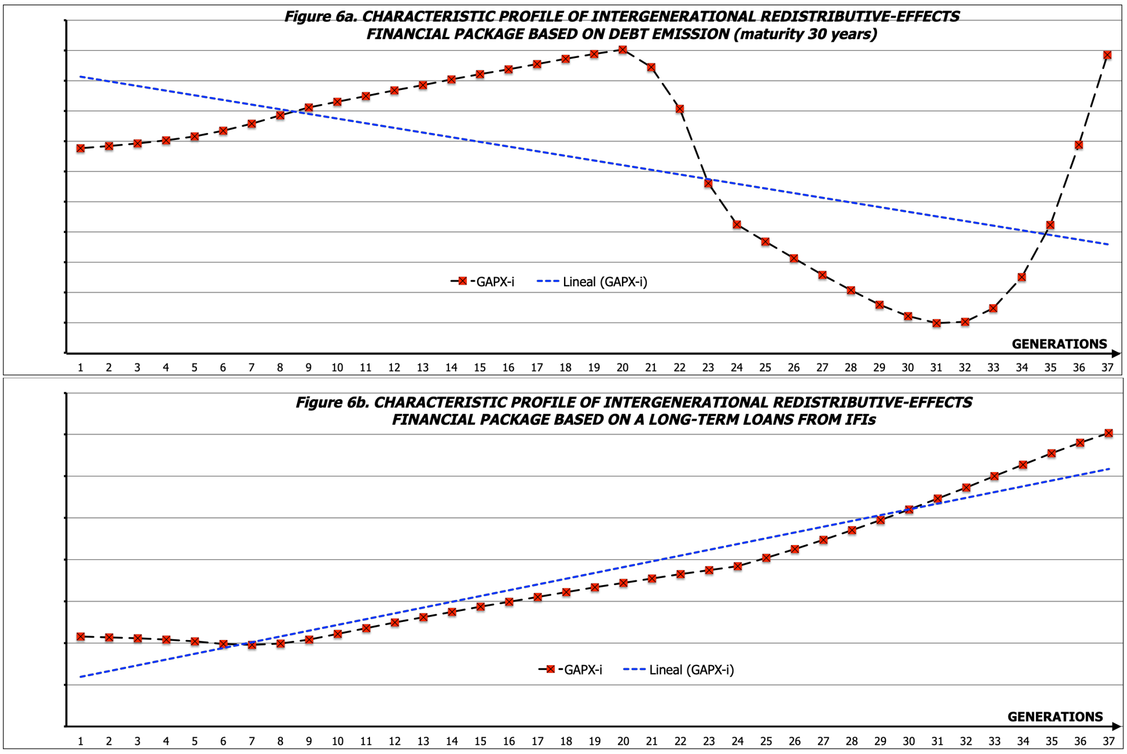
When using long-term loans, users and taxpayers will thus contribute in a more balanced way to fund the project, as shown in Figure 6b. Certain generations will suffer, in any case, from (small) negative gaps because some redistribution among generations exists. This might be disregarded or solved with some light measures. However, in the alternative scenario (debt emission), the

[10] Debt emissions and project bonds must be repaid to investors at maturity and are actually quite similar to bullet loans.

[11] Loans from public lending institutions (IFIs, national banks, etc.) that offer particularly good conditions in terms of duration, interest rates, grace periods, etc.

project appears as regressive besides very unfair (cf. Figure 6a), and thus it must be labelled as a white elephant.

Figure V-6. Time profile of the generational redistributive impact of the example



Source: Authors

The graphic analysis can be done with more precision using the IREM's outputs (cf. Table V-4). In the example, the metrics obtained show that, overall, the financing formula based on a long-term loan is useful to sustain the welfare of future individuals, even though *GUI= 59.5%,* meaning that around 60% of the (annual) generations affected will endure financial payments higher than the increase of resources obtained from the project (net benefits for the whole of society). The rationale is simple; being the differences between the value of the positive and the negative generational gaps so small *(IRESI=0.08),* and being theses generational gaps increasingly higher *(T&S= +17.2g),* the average of the gaps is positive when all the project lifespan is considered *($\overline{GAP}$= 0.86M€).* Accordingly*,* the project should be labelled as positive but unfair *(UF+)* from an intergenerational perspective. On the contrary, if the financing formula is based on debt emission, the project should be labelled as regressive from the intergenerational point of view. In this case, the intergenerational redistributive effects are really high *(IRESI=0.72)* and the level of usefulness of the project financing formula is negative *(T&S= –9.3g).* This means that early generations will obtain extraordinary (positive) gaps whilst the rest will bear financial burdens far above the actual net benefits provided by the project, as confirms a *GUI= 40.5%.* As a consequence, this financing formula has a negative impact on the welfare of future individuals *($\overline{GAP}$= –0.49M€)* and the project should be labelled as a *white elephant.*

Table V-4. IREM's outputs and project label for the financing scenarios of the example

Financing scenario:	*D1. Utility*		*D2. Performance*	*D3. Redistribution*	*Project Label*	*Intergenerational Impact*
	$\overline{GAP}$	*GUI*	*T&S*	*IRESI*		
Debt emission	*–0.49 M€*	40.5%	–9.3g	0.72	*RGS*	Regressive *(white elephant)*
Long-term loan	*0.86 M€*	59.5%	+17.2g	0.08	*UF+*	Positive but unfair

Source: Author

4.1. INTERGENERATIONAL EQUITY PATTERNS IN TRANSPORT INFRASTRUCTURE

The potential impact on project selection of using the proposed method to detect WEs, in particular regarding its last phase on intergenerational fairness, was analysed through the application of IREM to a sample of greenfield investments, mostly with the objective of assessing whether the model could be easily applied and if it produces the expected type of results. The typical lack of public information on projects, both on their CBA and on the specific financing formula finally adopted to carry them out, is a major problem in project financing research as such agreements are usually subject to commercial confidentiality. In this case it was possible, however, to use the authors' database for which the profiles of the socioeconomic net benefits *(B)* and the financing impact *(FI)* were available and could be studied in detail. Moreover, for these projects it was known whether the initial schedule of payments was maintained or not and what were the reasons for the changes (early repayment, additional loans to finance cost overruns, etc.).

It worth noting here that the funding structure is an integral part of the overarching financing mechanism chosen by the public promoter (GPI). The GPI establishes whether the user (totally or partially) or the taxpayer will end up paying for the investment in selecting the sources of finance for the implementation of the project and how the taxpayer will pay for the funding component falling on the public budgets, including their contribution to the financial blending in a PPP. For major transport projects, the GPI could decide to spread it out over time through long-term loans from commercial banks and/or IFIs. In this case, it can be assumed that the GPI will pay interests and reimburse the principal according to a pre-defined amortisation schedule, without possibility to recycle the loans once repaid, independently of such schedule. This rigidity is actually a main assumption used in IREM to calculate the time profile of the project's financial impact.

The GPI may also decide to obtain the required funds from the financial market through the emission of additional public debt, which usually can be recycled indefinitely. In this case, even though the bonds may have different maturity periods and be recycled, they are typically not linked to the asset (project). In IREM such additional public debt has been assimilated to a bullet loan with interests distributed throughout the project's life span. Thus, it has been assumed that the effects in the overall costs of the country's public debt are negligible.

The application of IREM, adopting the former assumptions, has allowed the comparison of the intergenerational effects of projects with similar characteristics (cf. Table V-5). The sample should not be considered representative of the universe of major transport investments, but its analysis would suggest that transport infrastructure projects tend to benefit future generations even if, in general, some generations tend to pay more than the net benefits they receive. Besides, the low average value of the redistribution index *(IRESI)* indicates that the effects are not very strong, although substantial differences between types of projects do exist. As already mentioned, due to the small sample size of some sub-sets, these results should only be considered representative of the concrete set of projects analysed and should not be used to infer general conclusions on the different infrastructure types.

According to the IREM's outputs, both for the high-speed railway (HSR) and the joint projects in the sample indicate that all affected generations obtain benefits that are higher than the actual payments they have to bear ($GUI_{average} = 0\%$ with $GUI_{sd} = 0.0$). For both sub-samples $T\&S > 0$, which shows a positive bias toward future generations, even though there exist some differential effects among generations ($IRESI_{average} > 0$). As a result, according to the flow chart shown in Figure V-1, they could be labelled *"fair and positive investments for future generations"*, provided that they have overcome the previous tests on efficiency, etc.

Table V-5. IREM statistical outcomes by type of project (*)

Type of infrastructure	Sample Size	*GUI*		*Trend & Slope (T&S)*		*IRESI*	
		average	sd	average	sd	average	sd
Total sample	**22**	**5.3%**	**12.2**	**+64.8g**	**28.4**	**0.14**	**0.20**
HSR projects	3	0.0%	0.0	+86.9g	8.9	0.32	0.28
UPT projects	9	12.2%	17.2	+54.9g	34.6	0.11	0.20
Motorway projects	8	0.8%	2.2	+67.1g	25.8	0.13	0.19
Joint projects	2	0.0%	0.0	+66.9g	13.2	0.04	0.03

(*) Low values for *GUI* and *IRESI* with sound positive values for *T&S* imply that, overall, the intergenerational impact of the projects in the sample should be considered positive.

Source: Author's database

For the group of projects within the UPT sample, which consists of investments in both metro and tramway infrastructure to extend the UPT network in different metropolitan areas, the results of the model indicate that most generations obtain positive gaps *($GUI_{average}$<13%)*. On the other hand, intergenerational redistribution appears as rather unimportant *($IRESI_{average}$=0.11)* and the evolution over time of the projects' effects on the concerned generations is positive *(*$T\&S_{average}$*=+54.9g)*. Thus, the overall intergenerational impact of the UPT projects should be considered as fairly positive even if the financial structure appears as controversial for a number projects *(GUI_{sd}=17.2)*. This signals that there might be an equity issue and therefore it is necessary to analyse in depth the adopted financial model and the impacts on the annual generations concerned, which are the inputs behind the IREM's indicators. It must be pointed out that equity issues are not always sufficient to label as WEs projects that were previously considered as efficient and financially sustainable from a traditional approach.

The results of the model for investments in motorways suggest that the sample, if the projects have passed the feasibility tests, does not contain WEs (*$GUI_{average}$=0.8%* with *GUI_{sd}=2.2*). They tend to benefit future generations *($T\&S_{average}$=+67.1g)*, although there are significant variations on the intensity of the benefits (*$T\&S_{sd}$=25.8)*. However, it must be taken into account that all the projects in the database are PPPs channelled through special purpose vehicles (SPVs)[12] holding long-term concessions based, in turn, on design-build-finance-maintain & operate (DBFMO) contracts. Hence, the financial structures shown in Table V-6 cannot be considered representative of the whole motorway sector. The IREM indicators for both motorway and bridge projects (road sample) suggest that: a) on average, the overlapping generations affected by these projects do not pay more than the benefits they receive from the investments; b) the statistical outputs do not reflect important intergenerational redistributive impacts *($IRESI_{average}$=0.07; $IRESI_{sd}$=0.16)*; and c) whilst the sample should not be deemed representative of the global road project population, it can be argued that, when channelled through PPPs, most road investments seem to be fair regarding the intergenerational redistribution effects.

In short, the transport infrastructure projects in the sample show, in general, a positive bias toward future individuals *($T\&S_{average}$=+64.8g)*, even if concrete annual generations tend to pay more than the net benefits they receive (*$GUI_{average}$=5.3%)*. Moreover, the average value of the *IRESI* suggests that the intergenerational redistributive effects amongst generations are not very strong *($IRESI_{average}$=0.14)*, although differences among projects do exist *($IRESI_{sd}$=0.20)*.

[12] The investment vehicle chosen by the GPI to develop transport infrastructure projects may be totally public, being managed by the Administration itself or by a public agency or company, or totally or partially private (usually through an SPV) when carried out through a PPP.

Table V-6. Financial structures of the motorway projects in the sample

CASE STUDY				FUNDING SOURCES					FINANCING		
Project code	Year of reference	Delivery model	Type of PPP	UE grants	GPI budgetary contributions (to CAPEX)	Revenues from users	GPI subsidies (to OPEX)	Private Finance	From additional public debt	Long-term loans from IFIs to the GPI	Loans from commercial banks to the GPI
04/006-01	2007	Concession contract (PPP/private finance)	DBFMO	–	0%	34.0%	4.6%	30.0%	31.4%	0%	0%
06/100-02	2012			–	2.3%	9.0%	38.4%	24.2%	26.0%	0%	0%
07/004-01	2003			–	2.0%	47.0%	2.6%	31.8%	16.6%	0%	0%
07/006-02	2006			–	8.8%	28.8%	1.7%	38.3%	22.4%	0%	0%
07/006-03	2006			–	6.6%	46.8%	0.4%	35.3%	10.9%	0%	0%
07/006-05	2006			–	5.8%	25.5%	6.6%	41.6%	20.5%	0%	0%
07/007-06	2007			–	0%	16.6%	26.2%	30.8%	26.4%	0%	0%
08/908-01	1998			–	0%	30.8%	30.8%	24.6%	13.9%	0%	0%

Source: Author's database

5. A CASE STUDY: TOLL-FREE MOTORWAYS OF ANDALUSIA (SPAIN)

IREM has been applied to a set of different toll-free stretches[13] of motorways that the Agency of Infrastructures of Andalusia (Spain) intended to build in the early 2010's as part of a strategic transport plan of regional scope. In projects "05/007-04" and "05/102-05" demand forecasts mainly depend on the GPI's estimates on the ability of the new motorways to gather existing traffic from disperse routes in target areas, while in project "05/102-06" some 50% of the yearly demand forecasts comes from induced traffic as it was expected that this toll-free motorway would increase the economic activity in the surrounding area. As the purpose of this exercise is to show how IREM can be used to detect WEs, the early steps of the phase "project analysis" shown in Figure V-1 (implications from regulations, environmental impact assessment, etc.) and, in particular, the analysis on whether estimates on costs and benefits and demand forecasts were biased or not and other factors affecting the quality of the CBA falls out of the scope of this paper. The taxes expected to be collected from the additional fuel consumption of induced traffic have been considered in the analysis of intergenerational impact, as they do have an impact in the IREM model.

Table V-7. Economic and Financial Rates of Return of the Andalusian motorways

Project ID	*Project Description*	*ENPV $_i$*	*ERR$_i$*	*FRR$_i$ $^{(*)}$*
05/007-04	Autovía de la Almanzora. Tramo Baza-Purchena	12.9 M€ (SDR=5.0%)	5.4%	10.7%
05/102-05	Autovía A-306. Tramo Torredonjimeno-El Carpio	52.8 M€ (SDR=3.0%)	4.0%	11.7%
05/102-06	Autovía de la Cuenca Minera. Conexión N-435 con A-66	71.0 M€ (SDR=4.5%)	9.2%	11.6%

$^{(*)}$ Financial rate of return values correspond to the project's overall profitability for the private investors[14].

Source: Author's database

[13] Relevant information has been obtained from the Government of Andalusia (Junta de Andalucía) official website; *"Estudio de viabiidad económico-financiera para la construcción, conservación y explotación";* contract dossiers n. 1-AA-2900-1.0-0.0-EG (Autovía del Almanzora en la A-334. Tramo Baza-Purchena), n. 1-AA-2902.0-0.0-EG (Autovía de la Cuenca Minera. Conexión de la N-435 con la autovía A-66, Ruta de la Plata) and n. 1-AA-2905-2.0-0.0-EG (Autovía A-306. Tramo Torredonjimeno – El Carpio).

[14] The overall profitability for the private investors has been calculated comparing both the cash-outflows needed for the SPV to complete the whole investment and the SPV's set-up costs with the cash-inflows expected for the concessionaire before debt repayment during the concession period. To calculate the profitability for investors, the overall capital invested by the SPV has been compared with the overall income for the SPV during the concession period once debt amortisation and interests as well as other legal provisions are discounted. Finally, the profitability for the equity holders has been calculated comparing it with the revenues for the SPV after debt repayment.

The assessments performed by the Spanish GPI indicate that the projects should not be considered as *white elephants* (cf. Table V-7), as socioeconomic CBAs showed positive results and the high financial return for the private sector indicated that the projects were financially sustainable provided that the Agency would have sufficient budget to pay for the envisaged availability payments[15]. It is worthwhile noting that such studies ("screening of socioeconomic viability" and "financial analysis" in Figure V-1) were produced in the context of the Financial Crisis (2007-2012), when the use of concession contracts was considered to be a good option to attract private financing to (provisionally) relieve public budgets, and also that, according to the authors' knowledge, the Agency of Infrastructures of Andalusia did not run any analysis on equity considerations once the decision to carry out the projects was adopted.

The proposed financing structure was based on a DBFMO agreement establishing that the concessionaire finances the totality of the project construction as well as the operation and maintenance costs. The GPI pays a yearly concession fee, subject to availability conditions, once the motorway is implemented. The yearly "availability payments" depend on the accomplishment of pre-defined objectives on quality and safety for the motorway as well as on certain operation obligations regarding critical aspects in case of emergency situations. The availability payment can increase if demand rises above certain pre-defined limits. The conditions described in the payment mechanism imply that the GPI will practically always pay the maximum yearly concession fee, as the factors that could somehow reduce it depend on availability criteria with minimum-service requirements that are easily achieved and are subject to self-monitoring. This financing formula appears well suited for institutional investors, as any experienced concessionaire could be expected to obtain reasonable financial profits for equity investors and guarantee the restitution of the funds obtained from funding institutions, while the risks of incurring in losses are quite limited.

5.1. ANALISYS OF INTERGENERATIONAL IMPACT

The IREM's outputs for the Spanish motorways (cf. Table V-8) indicate that most generations of taxpayers will pay for the projects whilst a few users will obtain net benefits *($GUI_{average}$=69.8%)*. Furthermore, as $\overline{GAP} < 0$, because gaps between the socioeconomic net benefits and the financial provisions are negative for most generations in projects "05/007-04 and 05/102-05", the indicators *T&S* and *IRESI* are not really relevant for the analysis of intergenerational impact (see Table V-2). As a result, these two projects should be labelled as "very unfair" *(VUF)* and regressive *(RGS)* respectively. By contrast, project "05/102-06" obtains a $\overline{GAP} > 0$ as well as a *T&S>0* despite GUI≈*40%* and, thus, the intergenerational impact of the project "05/102-06" could be considered positive but unfair, so the project is labelled as *"UF+"*.

Table V-8. Main results from IREM for the Spanish motorway projects

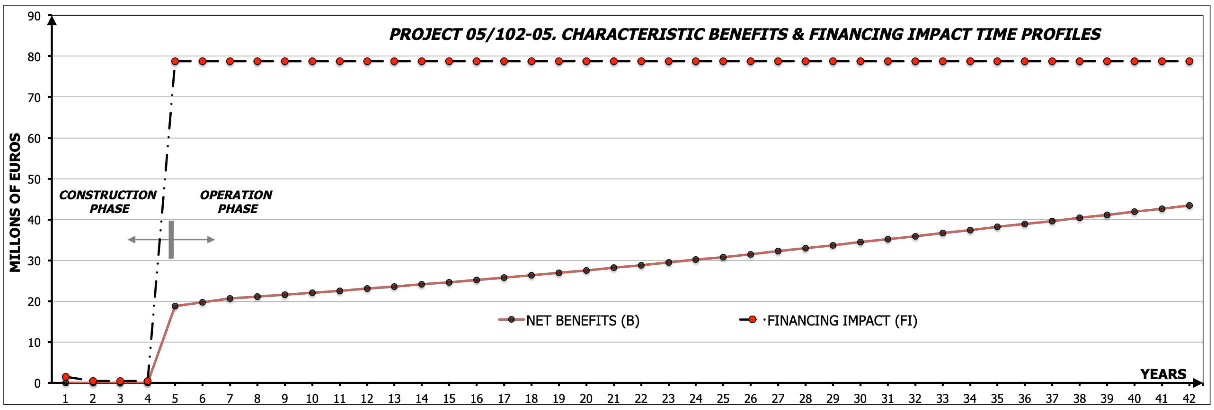
PROJECT		*IREM's OUTPUTS*					*Project Label*
Project ID	Type of Infrastructure	$\overline{GAP}$	*SD*	*GUI*	*T&S*	*IRESI*	
05/007-04	Toll-free motorway	*−6.7 M€*	*10.8 M€*	68.8%	+40.7g	0.13	*VUF*
05/102-05	Toll-free motorway	*−47.1 M€*	*6.6 M€*	100%	−7.0g	0.97	*RGS*
05/102-06	Toll-free motorway	*3.6 M€*	*8.3 M€*	40.6%	+36.8g	0.03	*UF+*

Source: Author

[15] An interesting digression would be to check why the Junta would not use available EU funds for these investments. Contrary to upfront grants, availability payments are not eligible to ERDF or other grant programmes.

The singularities of the motorway project with code "05/102-05" are particularly striking. The payments borne by the individuals affected (taxpayers) are higher than the socioeconomic net benefits generated by the project (cf. Figure V-7), which suggests that demand expectations could be seriously flawed (biased). As a consequence, it is highly likely that the results of a properly executed CBA, using an appropriate discount rate, would have recommended against this PPP. In intergenerational terms, the gap for any generation is negative, meaning that the project will deliver poor net socioeconomic benefits over the years for the whole of the society in comparison with the financial provisions that the future taxpayers will endure as a consequence of the financing formula adopted (cf. Figure V-8).

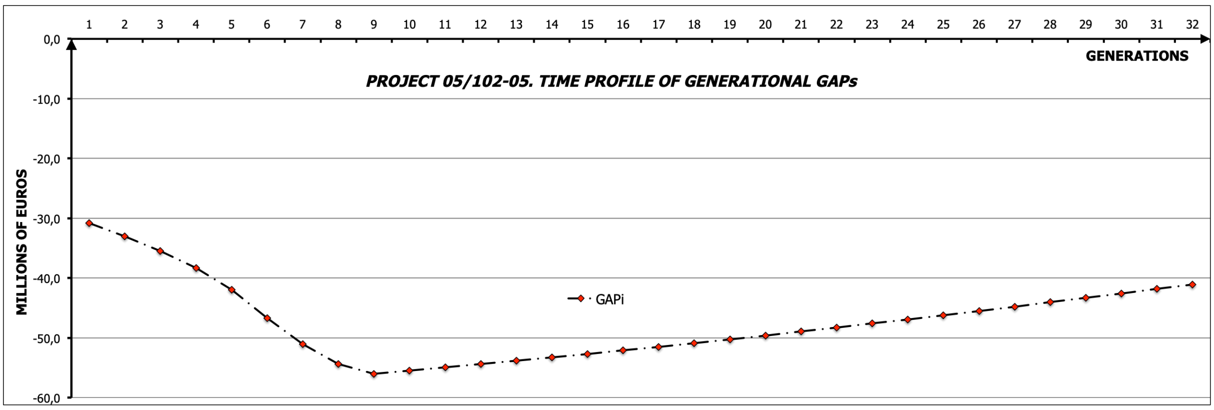
Figure V-7. Socioeconomic and financial time-profiles of the project "05/102-05"



Source: Author

This simple analysis does not provide information about whether some generations are more or less affected by the financial model than others, but it is clear that equity issues will arise during the project lifespan due to the financing formula adopted by the Andalusian Agency. The project's net benefits and the financing impact during the construction phase (cf. Figure V-7) appear quite balanced but, from the time of project commissioning, the financing requirements are twice the increase in resources obtained for the whole of society. As a result, every annual generation involved in the project "05/102-05" obtains a negative gap (cf. Figure V-8).

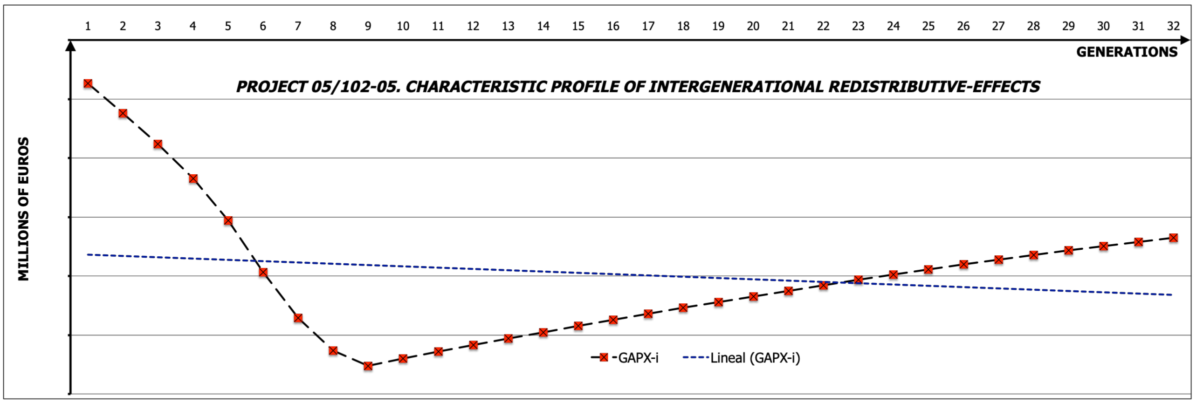
Figure V-8. Time profile of the generational gaps of the project "05/102-05"



Source: Author

Moreover, this project has a negative trend *(T&S = – 7.0g),* even though the slope is very small (cf. Figure V-9). This means that, while its rather low ERR may be deemed acceptable, the project's redistributive effects appear as regressive to future generations and thus would be a potential drag on the economy in the long run. Moreover, the financing formula leads the indicator of redistribution to its maximum rate *(IRESI = 0.97),* which means that there are strong divergences among the generations involved regarding (and irrespective of) the general trend of the project. As shown in Figure V-9 the gaps for generations 6 to 22 are below the line that represents the locus where the gaps average is null (dashed line), meaning that they will be adversely affected by the negative gaps of the project with more intensity than generations 1 to 5 and 23 to 32 above the dashed line.

Figure V-9. Time profile of the generational redistributive impact of the project "05/102-05"



Source: Author

In sum, the outcomes provided by the GPI for the motorway project "05/102-05" suggest that this investment could be viable for Andalusia as it shows an acceptable socioeconomic profitability (ENPV= 57.8 M€; ERR=4.0%; B/C=1.14). Besides, regarding the financing formula explained before, the business case appears as a cost-effective operation for the set of private investors as 1) the earning generated by the project widely exceeds its anticipate costs (FNPV=321.52M€), 2) the opportunity cost linked to this operation is soundly covered by the equity return (FRR=11.7%) and, 3) the project will pay for itself in an acceptable period of time (Payback period: 8 years).

Similar conclusions can be achieved for the case of institutional investors (FNPV=242.12M€; FRR=13.1%; Payback period: 12 years) and equity holders (FNPV=207.48M€; FRR=11.7%; Payback period: 13 years). Accordingly, it is also an attractive business case for private credit entities. Nonetheless, from the intergenerational perspective, the IREM's outputs indicate that this project should be labelled as regressive because no overlapping generation within the project lifecycle obtains net benefits higher that the corresponding financial burden and, furthermore, the financial burden is increasingly higher than the expected socioeconomic net benefits for the generations involved. It could be argued that part of the payments made by users and taxpayers are returning to their generation through the financial profits of private stakeholders which, in this case, seem relevant. The intergenerational effects of these profits have been disregarded. Besides the difficulties of getting the required information on amounts and distribution over the years, a subject to be eventually developed for the IREM, the flows involved should be modest and, in principle, of similar value over the years and have, therefore, little effect on the model outcomes.

The financing formula chosen by the Agency of Infrastructures of Andalusia to develop its regional road network through DBFMO agreements also appears as unfair from an intergenerational perspective for the two projects with $\overline{GAP} < 0$, but with special intensity for the project "05/102-05", where *GUI=100%.* The IREM's outcomes suggest that the Agency should have chosen better financing structures for these projects[16] ("05/007-04" and "05/102-05").

[16] It seems, however, that the model is fashionable, at least in Spain. The PIC (the Investment Plan in the national Road Network of Spain) promoted by the former national government during the first half of 2018 in general and, in

In short, although there is a need for additional research with larger samples of case studies, these results indicate that the combination of projects showing modest usefulness from a socioeconomic point of view –in terms of CBA outputs– and inappropriate financing formulae may potentially result in redistributive effects that are very unfair, even regressive, for generations to come. When the envisaged overall utility of the project in terms of resources for the successive generations is not substantial, it is possible that the actual financial charges linked to the main investment that future taxpayers will have to bear are so high that the project should be labelled as a *WE* due to the unfairness of the resulting intergenerational redistribution.

In the particular case of the motorway projects 05/007-04 and 05-102/05, both the negative average of the generational gap (intergenerational utility) and the negative intergenerational performance are a result of poor project's socioeconomic benefits over the years in combination with the financial burden linked to the PPP arrangements intended by the Agency of Infrastructures of Andalusia. It could be argued that the harmful intergenerational effects could be avoided with a shorter concession period or reducing the profits expectations for the private agents involved. However, an experienced analyst might judge the demand forecasts as overoptimistic. A more realistic scenario would result in lower net benefits, which also affect the GAP values. On the other hand, even if there is a real motive to adopt PPP solutions to expand the road network of Andalusia, there are probably other sustainable financing solutions that would be fairer to future generations. DBFMO contracts are a development solution for transport infrastructure that very often entail a substantial increase of the public expenditure linked to the project compared to other solutions based on conventional public procurement contracts (Penyalver et al., 2019). It is surprising that none of the agents involved in the financing process seemed to have observed that, for both projects[17], the yearly financial provisions during the project life cycle were, overall, higher than the (high) estimates of yearly socioeconomic net benefits.

6. CONCLUSIONS

The white elephant concept refers to integrated investment programmes or major infrastructure projects apparently convenient for society that, however, represent a severe misallocation of society's resources. This misallocation is typically related to the results of a cost-benefit analysis. Although efficiency should be the main concern of the government promoting the investment, CBA, which measures the socioeconomic efficiency of the project from the perspective of the society at the time when the decision to invest is taken, is often not the real determinant of investment decisions. Financial considerations are often critical in such decisions and they are not always leading to adequate solutions. In any case, a main concern of any decision-maker should be that financial structuring ensures that all major participants in the project are able to comply with their liabilities. Even efficient projects may become WEs if their financial sustainability is not properly ensured through adequate long-term commitments with capacity to prevent potential cash shortfalls.

---

particular, the project "Eje Norte-Sur de Murcia" (Eje viario alternativo a la autovía A-30 entre Archena y el enlace la Paloma), which counts on the support of the European Investment Bank (EIB) and the European Fund for Strategic Investments (EFSI), replicates, with small differences, the main distinctive features of the financing formula used by the Agency of Infrastructures of Andalusia (explained in the introduction of Section 4).

[17] Only the project with code "05/007-04" was actually tendered and awarded under private finance, through a PPP, in 2007. Before the start of the works, the GPI decided to cancel the concession contract and to carry out this project under a traditional contracting-out model. This decision was appealed to the Court of Justice by the concessionaire. At the moment, the concessionaire still claims millions in compensation.

The project's redistributive effects could also derail the implementation of a project and convert it into a WE, as they may have strong negative impacts on specific project stakeholders or on social and territorial groups. The lack of a comprehensive procedure to detect potential WEs could favour, in practice, that decision makers base their investment decisions on political grounds rather than on a proper analysis of their long-term effects for the agents concerned.

The aim of this paper is the development of a methodological proposal to detect WEs. Its focus is, however, on the long-term impacts of the project, which are those that characterise WEs. The discounting process of the standard CBA expresses a "present generation" approach. Incorporating the intergenerational redistribution effects in project appraisal means going beyond this approach. The comparison of net benefits with the actual financial payments of users and taxpayers (who are finally paying for the loans and other financial mechanisms used to structure the finance of the project) for the various generations affected during the long project cycle, through a specific model (IREM), allows assessing the fairness of the redistribution of the project effects across these generations.

IREM has been applied to a set of projects of different typologies. The results indicate that this model is suited to perform a proper analysis of intergenerational redistributive effects. The IREM indicators offer valuable insights to identify those projects that would represent a clearly unfair treatment of future generations, in spite of showing an acceptable socioeconomic return for the current society. A major finding of this research is actually that projects showing modest usefulness from a socioeconomic point of view may easily entail redistributive effects that are very unfair, even regressive, for generations to come, when they are implemented through inappropriate financing formulae and should be labelled as a WE.

The IREM's outputs may help public managers to both 1) prove that the investment-strategy's, i.e. the combination of project's effects and financial package, is useful to sustain the well-being of future generations; and 2) adopt financing formulae that smooth down the redistributive effects among the successive generations involved in long-term investments. The paper analyses, in more detail some Spanish motorway concession projects that the Government of Andalusia intended to carry out by having recourse to DBFMO contracts. Whilst this financing mechanism allows to align the financial provisions (yearly payments through a concession fee) with the project performance in the long run, the results show that some projects, which could appear acceptable under the traditional decision-making process, entail financial implications that make them very unfair for future generations and should thus be considered white elephants. Either the funding formula should be modified or the motorway in question should not be built under the current delivery model.

Finally, the results of this research stress that the financing formula of major transport infrastructures, which are very often defined at the later stages of decision-making, should be considered earlier and as a key factor of the process, both to check their financial sustainability and the compliance with the principle of intergenerational fairness.

7. REFERENCES

- Ansar, A., Flyvbjerg, B., Budzier, A. & Lunn, D., 2016. Does infrastructure investment led to economic growth? Evidence from China. Oxford Review of Economic Policy, 32(3), pp.360-90.
- Appel, H.C., 2012. Walls and white elephants: Oil extraction, responsibility, and infrastructural violence in Equatorial Guinea. Ethnography, 13(4), pp.439-65.
- Auerbach, A.J., Gokhale, J. & Kotlikoff, L., 1994. Generational Accounting: A Meaningful Way to Evaluate Fiscal Policy. Journal of Economic Perspectives, 8(1), pp.73-94.
- Ascher, W. & Krupp. C., 2010. Distributional implications of alternative financing of physical infrastructure development. In Physical Infrastructure Development: Balancing the Growth, Equity, and Environmental Imperatives (pp.35-68). Palgrave Macmillan, New York.
- Bang, K. & Banister, D., 2009. Assessment of large transport infrastructure projects: The CBA-DK model. Transportation Research Part A, 43, pp.800-13.
- Berechman, J., 2009. The Evaluation of Transportation Investment Projects. New York: Routledge.
- Beyazit, E., 2011. Evaluating Social Justice in Transport: Lessons to be Learned from the Capability Approach. Transports Reviews, 31(1), pp.117-34.
- Bradford, D.F., 1997. On the uses of benefit-cost reasoning in choosing policy towards global climate change. (No. w5920). National Bureau of Economic Research.
- De Palma, A., Picard, N. & Andrieu, L., 2012. Risk in transport investments. Networks and Spatial Economics, 12(2), pp.187-204.
- DG-Regio, 2015. Guide to Cost-Benefit Analysis of Investment Projects. Economic appraisal tool for Cohesion Policy 2014-2020. Brussels, Belgium: Directorate-General for Regional and Urban Policy of the European Union.
- Engel, E., Fischer, R. & Galetovic, A., 1997. Infrastructure franchising and government guarantees. In M.K.G.E.P.&.M.T. Timothy Irwing, ed. Dealing with public risk in private infrastructure. Washington D.C.: World Bank Latin American and Caribbean Studies Viewpoints. pp.89-105.
- Evans, D. & Sezer, H., 2004. Social discount rates for six major countries. Applied Economics Letters, 11, pp.557-60.
- Ferreira, F. & Peragine, V., 2015. Equality of Opportunity: Theory and Evidence. Policy Research Working Paper. World Bank Group.
- Flyvbjerg, B., 2007. Cost Overruns and Demand Shortfalls in Urban Rail and Other Infrastructure. Transportation Planning and Technology, 30(1), pp.9-30.
- Flyvbjerg, B., 2014. What You Should Know About Megaprojects and Why: An Overview. Project Management Journal, 46(2), pp.6-19 http://doi.org/10.1002/pmj.21409
- Flyvbjerg, B., Holm, M.S. & Buhl, S., 2002. Underestimating costs in public works projects, error or lie?, 2002. J. Am. Plann. Assoc.
- Fosgerau, M., 2007. Using nonparametrics to specify a model to measure the value of travel time. Transportation Research Part A, 41(9), pp.842-56.
- Ganuza, J.J. & Llobet, G., 2017. The Simple Economics of White Elephants. Working Paper http://www.cemfi.es/~llobet/papers.html
- Gollier, C., 2011. Pricing the future: The economics of discounting and sustainable development. Princeton University Press.
- Groom, B., Hepburn, C., Koundouri, P. & Pearce, D., 2005. Declining Discount Rates: The long and the Short of it. Environmental & Resource Economics, 32, pp.445-93.
- Hahn, R.W. et al., 2000. Assessing regulatory impact analyses: The failure of agencies to comply with Executive Order 12,866. Harvard Journal of Law and Public Policy, 23(3), pp.859-85.
- Harris, E. & Kende-Robb, C., 2008. Integrating Macroeconomic Policies and Social Objectives: Choosing the Right Policy Mix for Poverty Reduction. New Frontiers of Social Policy, pp.97-120.
- Henderson, N. & Bateman, I., 1995. Empirical and public choice evidence for hyperbolic social discount rates and the implications for intergenerational discounting. Environmental and Resource Economics, 5(4), pp.413-23.
- Henisz, W.J. & Zelner, B.A., 2006. Interest groups, veto points, and electricity infrastructure deployment. International Organization, 60(1), pp.263-86.
- Hoyos, D., 2014. Sobre grandes infraestructuras, corrupción y elefantes blancos. Berria.

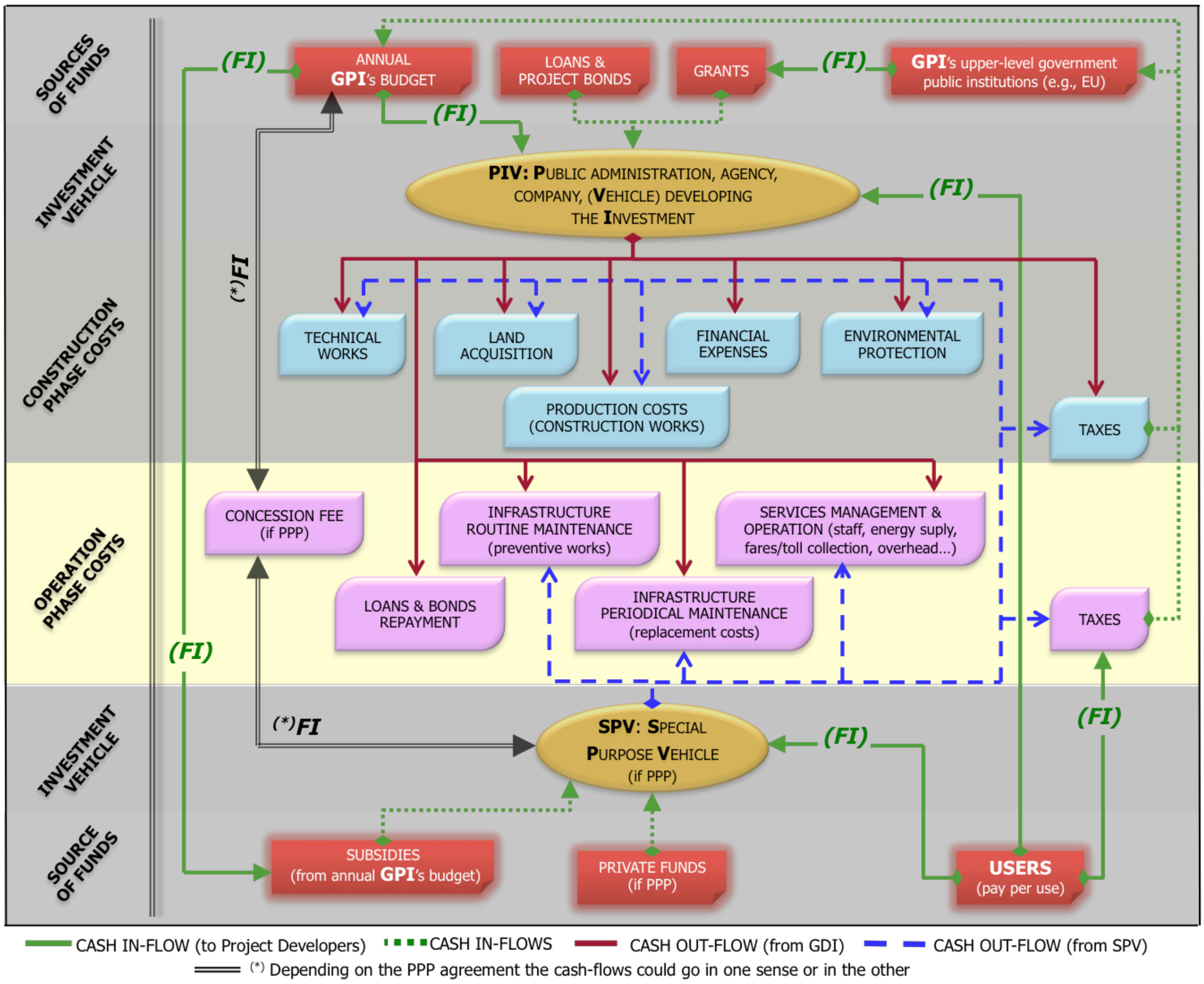
- ISR, 2017. The Panel Study of Income Dynamics (PSID). A national study of socioeconomics and health over lifetimes and across generations. PSID Main Interview User Manual: Release 2017. Institute for Social Research, University of Michigan.
- Kotlikoff, L., 1992. General Accounting -Knowing Who Pays, and When, for What We Expend. The Free Press (New York).
- Lave, L.B., 1996. Benefit-Cost Analysis. Washington, DC. AEI Press, pp. 104-134.
- Lee, J.Y. & Ellingwood, B.R., 2015. Ethical discounting for civil infrastructure decisions extending over multiple generations. Structural Safety, 57, pp.43-52.
- Leleur, S., Salling, K.B. & Jensen, A.V., 2007. Documentation and Validation of the TGB Evaluation model in Greenland. Technical Report prepared for the Home Rule Authorities in Greenland, Centre for Traffic and Transport, Technical University of Denmark.
- Litman, T., 1996. Using Road Pricing Revenue: Economic Efficiency and Equity Considerations. Transportation Research Record: Journal of the Transportation Research Board, 1558(1), pp.24-28.
- Litman, T., 2009. Transportation cost and benefit analysis. Victoria Transport Policy Institute, 31.
- Locatelli, G., Mariani, G., Sainati, T. & Greco, M., 2017. Corruption in public projects and megaprojects: There is an elephant in the room!. International Journal of Project Management 35, pp. 252-268.
- Mackie, P., Jara-Diaz, S.R. & Fowkes, S.R., 2001. The value of travel time savings in evaluation. Transportation Research Part E: Logistics and Transportation Review, 37(2-3), pp.91-106.
- Mangan, J.A., 2008. Prologue: Guarantees of Global Goodwill: Post-Olympic Legacies – Too Many Limping White Elephants? The International Journal of the History of Sport, 25(14), pp.1869-1883.
- Martens, K., 2006. Basic Transport Planning and Principles of Social Justice. Berkely Planning Journal, 19(1), pp.1-17.
- Martín, F., 1997. Justifying a high-speed rail project: social value vs. regional growth. The Annals of Regional Science, 31(2), pp.155-74.
- McCrae, M. & Aiken, M., 2000. Accounting for Infrastructure Service Delivery by Government: Generational Issues. Financial Accountability & Management, 16(3), pp.265-287.
- Merrow, E.W., 2011. Industrial Megaprojects: Concepts, Strategies and Practices for Success. Hoboken, NJ: Wiley.
- Meunier, D., Quinet, A. & Quinet, E., 2013. Project appraisal and long term strategic vision. In 41st European Transport Conference. Frankfurt, 2013. Elsevier.
- Nesticò, A. & Maselli, G., 2018. Intergenerational Discounting in the Economic Evaluation of Projects. In International Symposium on New Metropolitan Perspectives, pp.260-268. Springer, Cham.
- Penyalver, D. & Turró, M., 2016. Intergenerational Redistributive Effects of Transport Infrastructure Financing. Case Studies from European and Non-European Countries. STAREBEI report for the European Investment Bank Institute (Luxembourg). http://institute.eib.org/map/map.html
- Penyalver, D. & Turró, M., 2017. Assessing the Fairness of a Project Financing Formula on Successive Generations. International Journal of Transport Economics, 44(1), pp.153-176. https://doi.org/10.19272/201706701008
- Penyalver, D. & Turró, M., 2018. A Classification for the Redistributive Effects of Investments in Transport Infrastructure. International Journal of Transport Economics, 45(4), pp.689-726. https://doi.org/10.19272/201806704008
- Penyalver, D., Turró, M. & Zavala-Rojas, D., 2018. Intergenerational Perception of the Utility of Major Transport Investments. Research in Transportation Economic, 70, pp.97-111. https://doi.org/10.1016/j.retrec.2017.11.001
- Penyalver, D., Turró, M. & Williamson, J.B, 2019. Measuring the Value for Money of Transport Infrastructure Procurement; An Intergenerational Approach. Transportation Research Part A: Policy and Practice, 119, pp.238-254. https://doi.org/10.1016/j.tra.2018.11.013
- Pickrell, D.H., 1990. Urban Rail Transit Projects: Forecast versus Actual Ridership and Cost. Washington, DC: US Department of Transportation.
- Pilcher, J., 1994. Mannheim's sociology of generations: an undervalued legacy. British Journal of Sociology, 45(3).
- PMI, 2008. A guide to the project management body of knowledge. Project Management Institute, 4th ed.

- Papanikolaou, P., 2013. Athens 2004. Ten Years Later the Olympic Infrastructure, the Cultural Olympiad and the 'White Elephant' Syndrome. Journal of Power, Politics and Governance, 1(1), pp.1-9.
- Prasser, S., 2007. Overcoming the 'White Elephant' Syndrome in Big and Iconic Projects in the Public and Private Sectors. In Improving Implementation: Organisational Change and Project Management, pp. 47-67. Australian National University e-Press.
- Raftery, J., 2003. Risk analysis in project management. Routledge.
- Rasch, E.D. & Köhne, M., 2017. Practices and imaginations of energy justice in transition. A case study of the Noordoostpolder, the Netherlands. Energy Policy, 107, pp.607-614.
- Raux, C., Souche, S. & Mercier, A., 2006. De l'équité à l'acceptabilité des politiques de transport: que peut le calcul économique? CNRS, Université Lyon 2, ENTPE.
- Rawls, 1972. A Theory of Justice. Clarendon Press.
- Richard, E., 2008. Australia under construction: Nation-building: Past, Present and Future. ANZSOG Monographs , pp.49-56.
- Richmond, J.E.D., 1998. New Rail Transit Investments: A Review. Cambridge, MA: Harvard University, John F. Kennedy School of Government.
- Rius-Ulldemolins, J., Hernàndez i Martí, G.M. & Torres, F., 2015. Urban Development and Cultural Policy "White Elephants": Barcelona and Valencia. European Planning Studies, 24(1), pp.61-75.
- Robinson, J.A. & Torvik, R., 2004. White Elephants. Journal of Public Economics, 89(2), pp.197-210.
- Salling, K.B. & Banister, D., 2009. Assessment of large transport infrastructure pro- jects: the CBA-DK model. Transportation Research Part A: Policy and Practice, 43(9-10), pp.800-13.
- Scambary, J., 2015. In Search of White Elephants: The Political Economy of Resource Income Expenditure in East Timor. Critial Asian Studies, 47(2), pp.283-308.
- Scott, W., Raymond, E.L. & Ryan, J., 2011. Global Projects: Institutional and Political Challenges. Cambridge: Cambridge University Press.
- Thomopoulos, N., Grant-Muller, S. & Tight, M.R., 2009. Incorporating equity considerations in transport infrastructure evaluation: Current practice and a proposed methodology. Evaluation and Program Planning, 32, pp.351-59.
- Trannoy, A., 2011. Equity Dimensions of Transport Policy. In Handbook of Transport Economics. Edward Elgar Publishing.
- Turró, M., 2004. RAILPAG. Railway Project Appraisal Guidelines. European Commission and European Investment Bank.
- Turró, M., 2015. Sobre la toma de decisiones en las inversiones en transporte. Revista de Obras Públicas, 162(3565).
- US-GAO, 1998. Regulatory Reform: Agencies could improve development, documentation, and clarity of regulatory economic analyses. Report to the Committee on Governmental Affairs. US General Accounting Office; U.S. Senate. Washington, DC.
- Veebel, V., Ploom, I. & Markus, R., 2018. EU-Financed Peripheral Large-Scale Infrastructure Projects and the White Elephant Syndrome: the Example of Rail Baltica. Romanian Journal of European Affairs, 18(1), pp.113-128.
- Vickerman, R., 2007. Cost-Benefit Analysis and large-scale infrastructure projects: State of the art and challenges. Environment and Planning B: Planning and Design, 34(4), pp.598-610.
- Viegas, J.M., 2001. Making urban road pricing acceptable and effectivie: searching for quality and equity in urban mobility. Transport Policy, 8, pp.289-94.
- Wünderich, V., 2014. El nuevo proyecto del Gran Canal en Nicaragua: más pesadilla que sueño. Encuentro, 97, pp.24-35.
- Williams, T., Knut, S. & Kjell, S., 2009. Making Essential Choices with Scant Information: Front-end Decision Making in Major Projects. Springer.
- Williamson, J.B. & Rhodes, A., 2011. A critical assessment of generational accounting and its contribution to the generational equity debate. International Journal of Ageing and Later Life, 6(1), pp.33-57.
- World Bank, 2013. Inclusion Matters: The Foundation for Shared Prosperity. Washington, DC: New Frontiers of Social Policy.

8. APPENDIX A: COMPUTATION OF THE IREM INDICATORS; AN OVERVIEW

IREM[18] is an overlapping generations model that allows to compare the time profile of the net socioeconomic benefits *(B),* obtained from the annuities of the CBA, produced by a project with the time profile of the financing impact *(FI)* stemming from the project's financing formula through the concept of "annual generation" (Penyalver & Turró, 2017). As FI is determined by the payment schedule foreseen for the project that users and/or taxpayers are bound to honour, through the investment vehicle chosen by the GPI, the *FI* time profile includes tolls, fees, etc. levied on the various users and/or the funds devoted to the project coming from the public budgets either to reimburse the loans (principal and interests) assigned to the project or to pay for the investment, operation and maintenance costs not covered by the former loans (cf. Figure V-A1).

Figure V-A1. Key sources of financing and links of cash in/out-flows to obtain the financing impact (FI)



Source: Penyalver & Turró, 2017

There are a number of steps that the analyst must follow to perform a proper analysis of the project's intergenerational impact. Following Penyalver & Turró, 2017, the first step consists of calculating the difference *(D_i)* between net benefits value *(B_i)* and financing impact *(FI_i)* for each year, i, across the project life cycle.

[18] This Appendix is a synthesis of the original paper that describes the IREM model: "Assessing the fairness of a project financing formula on successive generations" (Penyalver & Turró, 2017)

Next, it is possible to calculate the gap for each annual generation *(GAP_i)* from the weights *(w_j)* of the *weighting curve*[19] that represents a standard annual generation in IREM (cf. Equation V-A1).

Equation V-A1.Calculation of the GAP for an annual generation in year i

$$GAP_i = \sum_{i-j}^{i+j} D_j \cdot w_j \ ; \ \sum_{i-j}^{i+j} w_j = 1$$

The times profile of the generational gaps allows to identify how the financing burden is shared each year between users and taxpayers and what is the gap between the net benefits from the project and the amounts paid. As negative gaps are perceived more strongly than positive ones, with the size of these positive effects being relatively irrelevant, the existence of a potential problem of unfairness treatment can be simply quantified through the *Generational Unfairness Indicator (GUI),* which gives the percentage of the number of generations with negative gaps (NEGAP) over the total annual generations (N) considered (cf. Equation V-A2).

Equation V-A2. Calculation of GUI

$$GUI = \left(\frac{NEGAP}{N}\right) \cdot 100$$

To calculate the rest of the IREM's indicators, it is necessary to use a common baseline to compare the intergenerational effects of different options available to finance them. In order to do so, the analyst has to calculate, first, the average value of the different generational gaps obtained along the project lifespan ($\overline{GAP}$) and, next, the *intergenerational gap (GAP_{intg-i})* for each year according to Equations V-A3 and V-A4.

Equation V-A3. Calculation of the $\overline{GAP}$

$$\overline{GAP} = \frac{\sum_{i=1}^{N} GAP_i}{N}$$

Equation V-A4. Calculation of the intergenerational GAP

$$GAP_{intg-i} = GAP_i - \overline{GAP}$$

The variations over the life cycle of GAP_{intg-i} indicate whether some annual generations are more or less affected by the financial model than others. However, as the impacts on society of future gaps are mitigated by the wealth growth of its members, which is usually measured through the GDP (gross domestic product), the above calculations have to be modified to take into account the reduced value of the gaps between expected net socioeconomic benefits and payments for generations[20] to come. It is done as shown in Equation V-A5, discounting from the GAP_{intg-i} series the long-term annual growth of GDP/c following an exponential pattern similar to the social discount rate. The modified intergenerational gap for each generation is represented as GAP_{X-i}.

[19] This concept has been presented in the epigraph 4 of this paper. The weights (inputs) to be used for the calculation of the GAP_i are also shown in Table 1 and Figure 3 of point 4.

[20] In IREM, the weights *(w_j)* for each year within an annual generation define, together with its timespan, the relevance for society of the project's effects considering the reduced value of non-central years. Reducing the GAP_{intg-i} values by means of the *GDP/c* aims at representing society's long-term wealth growth. Thus, each mechanism of time discounting has a different target and function (double discounting is avoided).

Equation V-A5. Calculation of modified intergenerational GAP

$$GAP_{X-i} = \frac{GAP_{intg-i}}{(1 + TC_{GDP/c})^{(i-1)}}$$

The distance of each GAP_{X-i} with regards to the geometrical line resulting from the linear regression of the whole intergenerational gap series allows determining whether a specific generation is more positively (or negatively) affected than others. The separation of the yearly values from the trend, represented through the coefficient of determination of the GAP_{X-i} series ($R^2_{GAP[X]}$), provides information about the redistributive effects that occur due to the financing formula of the project and how they affect different generations of users and taxpayers (intergenerational effects). To facilitate the understanding of the redistributive intergenerational effects, the model defines the *Intergenerational Redistributive Effects Sharing Index (IRESI),* which offers information on the overall intensity of the intergenerational redistributive effects (cf. Equation V-A6).

Equation V-A6. Calculation of IRESI

$$IRESI = 1 - R^2_{GAP\,[X]}\ ; \quad IRESI \in [0,1]$$

On the other hand, the trend of the best-fit line indicates whether, globally, the proposed financing structure will tend to (relatively) benefit or harm future generations. The slope of the regression gives the strength of the gap in favour of future generations. As a result, the indicator *"Trend and Slope" (T&S)* provides information about the evolution over time of the effects of the project on the concerned annual generations (intergenerational performance). The bigger the angle of the slope the highest will be the benefits for generations to come.

SECTION VI. MEASURING THE VALUE FOR MONEY OF TRANSPORT INFRASTRUCTURE PROCUREMENT; AN INTERGENERATIONAL APPROACH

Penyalver, D., Turró, M. & Williamson, J.B., 2019

Abstract

Cost-benefit analysis is essential for decision-making in connection with major transport projects and integrated investment programmes. Projects of transport infrastructure have traditionally been publicly promoted and managed, but funded through both public and private sources. While budget allocations are always somehow present, the financing of the project may involve private participation, including user fees and loans of various types. Actually, management models involving private actors have been increasingly used in recent decades. The background supporting this trend is that private ingenuity and expertise in dealing with risk improves overall project efficiency enough to compensate for the additional expenditure generated by these models. In addition, the government promoting the investment may use private finance as a mechanism to place it off-budget.

Current methods of project appraisal, in particular cost-benefit analysis, look at actions from the point of view of today's society. Decision makers usually determine the financing formula after the decision to build has been adopted, which should ideally follow a positive conclusion on the efficiency of the project. But the financing formula has an impact across the successive generations of users and/or taxpayers that will end up footing the bill stemming from the investment. This paper actually highlights the importance of looking closely at the intergenerational effects of the adopted financing mechanism to ensure its fairness and convenience. It describes the outcomes obtained from the analysis of the intergenerational impacts performed with IREM –a model developed precisely to analyse these effects– to a set of urban public transport infrastructure projects. The IREM results show that public-private partnerships, although often entailing a substantial increase of the public expenditure linked to these projects compared to conventional procurement mechanisms, are typically better in terms of intergenerational fairness. This conclusion cannot be extended to all PPPs, as it depends on the alternative public sector funding, but it is a strong argument in favour of including in the *Value for Money* analysis of PPPs, besides the standard efficiency and financial considerations, an analysis of the intergenerational effects of the different procurement options and to compare these effects with those of the purely public financing alternative

1. INTRODUCTION

The convenience of major infrastructure projects for society is typically determined through an analysis of efficiency by using cost-benefit analysis CBA (Bristow & Nellthorp, 2000; Meunier et al., 2013). The main advantage of CBA compared to other appraisal methods is that it allows decision makers to compare various alternative investment-options at a given point of time through simple key indicators of the project's efficiency (Thomopoulos et al., 2009). This is done using a discounting mechanism that, through the social discount rate, transforms future costs and benefits into an economic net present value (ENPV). The ENPV is actually a key indicator to measure the future utility of the project for the generation in which the decision is taken, as it represents the additional welfare for the present society, as a whole, generated during the project lifecycle (Gollier, 2011; Boardman et al., 2017). CBA is also considered critical for determining which projects are appropriate to be developed through public-private partnerships, PPPs (Saavedra & Bozeman, 2004; Burger & Hawkesworth, 2011). In this case, the question of interest is whether the *Value for Money*[1] *(VfM)* of alternative delivery models to *typical infrastructure procurement*[2] (TIP) is high enough to compensate the additional costs of locating trading partners and executing transactions under different forms of economic organisations and contractual arrangements (transaction costs). It is worth noting here that, in the socioeconomic CBA, the payments between the government agency (Government Promoting the Investment, GPI) and private actors will be treated as an expenditure on the public side that is fully compensated by the revenue for private actors within the period (year) the resources are consumed and generated (DG-Regio, 2015).

In the transport sector *VfM* typically refers to the (likely) additional efficiency for the whole society brought about by the private participation in project financing and management (EPEC, 2011; ITF, 2018). Infrastructure provision has been traditionally publicly financed, directly out of general tax revenues and usually by having recourse to some type of contracting-out mechanism (Vickerman, 2004). But in recent decades governments have been encouraged to favour private finance in an effort to access a wider range of resources and expertise (Bryson et al., 2006; Wood & Gray, 1991) as well as due to growing concerns over the recurrent budgetary deficits of public administrations (Debande, 2002; Vickerman, 2004; Vecchi et al., 2017). Private participation in project financing is not a new idea (Eichengreen, 1995); pure concessions and other types of PPPs have been traditionally used with the argument that they enhance project efficiency and efficacy, because PPP arrangements allow introducing incentives that can favour infrastructure delivery and service provision at the lowest costs (Hodge & Greeve, 2009; Eadie et al., 2013; Sarmento, 2014). The use of private finance can be, however, controversial. The private participation entails high transaction costs for projects unfolding over long timespans (Vining & Boardman, 2008) because PPP participants have different goals (Forrer et al., 2010) and, as the contracts cannot be fully specified (Hart, 2002; Soliño & Gago de Santos, 2010), there is a substantial amount of preparatory and monitoring work to be carried out that is much more cumbersome than in TIP.

[1] The *VfM* concept can broadly be defined as what a government judges to be an optimal combination of quantity, quality, features and costs, expected over the whole of the project lifespan (Burger & Hawkesworth, 2011). Although it is broadly defined in terms of economy, efficiency and effectiveness (Diamond, 2005), *VfM* is related to the idea that PPPs can produce a flow of services at least equivalent in quality to that which could be provided by the public sector but a lower overall cost (Sarmento, 2010). This increase in efficiency can be delivered through risk transfer, innovation, greater asset utilisation and integrated whole-of-life management (Fitzgerald, 2004).

[2] The concept "*traditional infrastructure procurement"* (TIP) refers to conventional public procurement contracts, separately awarded for construction and maintenance, traditionally used by a contracting public sector entity for infrastructure construction and services delivery (Debande, 2002; Burger & Hawkesworth, 2011).

From the point of view of society, the best way to provide infrastructure is the arrangement that better fulfils its agreed objectives. Obviously, a main objective is always the maximisation of efficiency in terms of resources that is commonly measured through CBA. There are, however, other critical aspects to judge. Vining & Boardman (2008) suggest that one potential criterion is that the GPI should seek to minimise the overall expenditure linked to the project, holding quality constant. However, decision makers usually determine the project's financing formula after the decision to build[3] has been adopted. As a consequence, the probable incidence of the formula on production costs is very often ignored, even though these costs could alter the ranking of infrastructure delivery models (Vining & Boardman, 2008). In addition, when dealing with long-term investments, the delivery model in general and, in particular, the financing formula chosen by the GPI have the potential to change the relation between the actual payments and the *net socioeconomic benefits*[4] apprehended over time by the individuals concerned, grouped in annual generations[5] (Penyalver et al., 2017). This could severely affect some of the objectives that were included in the initial considerations for the project construction. The desired fairness of the impacts distribution of the project over its lifecycle is particularly relevant for the decision-making process (Turró & Penyalver, 2019).

The *Intergenerational Redistributive Effects Model* IREM (Penyalver & Turró, 2017) is a microeconomic tool, complementary to traditional economic approaches and decision-making methodologies, that allows looking closely at the redistributive effects of the overall public expenditure from an intergenerational perspective (Turró & Penyalver, 2019). Major investments aiming at enhancing the welfare of different generations should contribute to meet the needs of the present without compromising the ability of future individuals to meet their own needs (sustainability condition). Thus, they cannot be fully justified without at least careful consideration of the impact on those who will be alive in the decades ahead, including those who are young today, or even unborn, and may end up bearing much of the actual payments in relation to the investment if it is funded with long-term debt. Actually, this paper shows that there is a need to go deeper into intergenerational redistribution effects to ensure the fairness of the adopted financial scheme. Taking an intergenerational approach in the decision-making of long-term investments and financial plans through IREM, which has been developed precisely to analyse these effects, can offer complementary insights on the *VfM* of the different financial structures for the same project.

The paper is organised as follows: The next section provides background on alternative financial mechanisms for infrastructure provision and points out key considerations surrounding the intergenerational redistributive effects of the overall expenditure involved in the development of major transport projects, whatever the specific delivery model. Section 3 provides arguments on why the metrics obtained from IREM provide valuable insights of the *VfM* for both TPI and PPP delivery model for any financial scheme. In section 4, the intergenerational impact analysis

[3] The time of making the decision to build the project is usually the time the project was formally given the go-ahead (Flyvbjerg, 2005). When this date is not available or representative, the date of project approval by the main financiers can be adopted as the time of decision.

[4] In IREM, *net benefits* refer to the difference between the resources generated and consumed annually by the project. Investment costs are, however, excluded from this calculation because the objective is to compare the impact of the project for the whole of society with the actual payment schedule stemming from the project's financing formula affecting both taxpayers and users. For more details see Penyalver & Turró (2017).

[5] Since Mannheim's "The problem of generations" (1923), the concept of "generation" or "social generation" has been used in the sense of "cohort", which refers to people within a delineated population who experience the same significant event within a given period of time (Pilcher, 1994). But the concept of "annual generation", which refers to the group of individuals affected by the effects of a major transport infrastructure project over time, is more explicit, as defines the number of years (or timespan) included in the (social) generation and allows representing the individuals' preferences on such effects through a survey-based weighting curve (Penyalver et al., 2017).

model (IREM) is applied to different financial schemes for a set of projects of transport infrastructure already developed within metropolitan areas. The aim of this effort is to deliver evidence on whether the added value of financial structures sustaining traditional infrastructure procurement is lower or not than for alternative public-private partnerships. Finally, Section 5 offers general conclusions and policy recommendations in terms of intergenerational fairness.

2. AN OVERVIEW OF THE INTERGENERATIONAL EFFECTS OF THE FINANCING STRUCTURE ADOPTED FOR INVESTMENT IN MAJOR INFRASTRUCTURE PROJECTS

2.1. MAIN EFFECTS OF FINANCING SOURCES FOR SOCIETY

Cost-benefit analysis compares the costs and the benefits of a project over its whole lifecycle. In socioeconomic CBA, the costs and benefits in terms of resources affecting those individuals belonging to the society of each year are estimated to assess if the project is worthwhile, i.e. efficient. This is done using a discount formula that gives an indication of the value of the project for the extant society (i.e. the Net Present Value, NPV), implying a progressive reduction of the weight of the effects the more remote they are. In terms of costs, most of the resources consumed are those linked to the construction phase and to the operation and maintenance (O&M) stemming from the investment. The benefits generated by major infrastructure projects come mainly from direct benefits to users (improved services, operating costs savings, safety improvements, etc.), as well as from other positive effects for users and non-users of the region where the investment takes place (e.g., increase in competitiveness, reduction in local pollution) and for the whole society (e.g., reduction in greenhouse emissions). Positive externalities related to indirect effects occurring in secondary markets, such as displacement of activities, which are irrelevant in a general equilibrium setting, are seldom taken into account in CBA, at least in the EU (DG-Regio, 2015), but negative externalities, in particular those related to the environment are getting an increasing weight in project evaluation.

The socioeconomic CBA assigns both costs and benefits to the year when the consumption and generation of resources occur. This is logical in terms of resource accounting, but it does not reflect what is actually happening. The positive effects of the project are indeed mostly perceived by individuals belonging to the society of the year in question, i.e. the users and, generally, the society "of each moment" (which can be referred as a "generation"). However, the actual money payments for the investment and its operation and maintenance are defined by the financing formula adopted. Such payments are ultimately made by users, through direct payments such as tolls, and/or by taxpayers feeding the public budgets contributing to the project.

Major infrastructure projects (transport projects, in particular) are traditionally funded by means of budgetary contributions. In this case, the contributions included in the budget annuities of the GPI during the construction phase are often covering only a small part of the total cost, so the GPI is bound to obtain loans of different characteristics, emit project bonds or use other mechanisms[6] to get the required short-term money availability to pay the construction bills. The common financing instruments for infrastructure investments are reimbursed over a long period to ensure the financial sustainability of the project, essential for its long-term success (Turró & Penyalver, 2019). On the other hand, it is worth stressing here that loans are "money transfers" that are not relevant for the CBA because they do not involve resource consumption or

[6] While public debt and even project bonds could have tenures of several decades, loans to specific projects hardly ever go beyond 25-30 years.

generation. Unless some of these money transfers are external to the "society", they are neutral in terms of resources[7].

The model that is chosen for infrastructure delivery, while not directly affecting socioeconomic profitability, has nevertheless a clear impact on public accounts (Boardman & Vining, 2010). Project-specific financial instruments are always checked for their public deficit/debt implications[8]. When they are strong enough, they may affect the cost of the GPI's debt emissions and therefore its expenditure opportunities and the options open to its future decision-makers. This "external" impact could be particularly strong when there are costs overruns and delays, which are quite common for major infrastructure projects (Flyvbjerg et al., 2018), as the consequent (and urgent) need for funds may have dramatic consequences on the GPI budget and its capacity to fund other priorities (Ansar et al., 2016).

When the GPI has severe macroeconomic constraints, decision makers tend to look for external financing sources, mainly investments from the private sector, notably through public-private partnerships (PPPs), besides grants[9] from higher-level administrations. By means of a PPP agreement the private partner (through a concession or another arrangement) may be given the responsibility for the design, construction, financing, operation and management of the asset to deliver a service to the GPI or directly to the end users, or both (Burger & Hawkesworth, 2011). This allows the public authority to act as a regulator and thus concentrate on service planning and performance monitoring instead of being tied up in the day-to-day supervision of works and delivery of services (DG-Move, 2018).

The main argument in favour of PPPs is that the public sector should benefit from private ingenuity and expertise in dealing with project risks, with a positive impact in project performance. Decision makers will highlight quality, economy in the use of resources, efficiency and effectiveness, and better performance standards (Akintoye et al., 2003; Diamond, 2005; Zhang, 2006) to justify the convenience of pure concessions or other types of PPPs. However, a main objective of a PPP will always be to reduce the public sector short-term funding needs and to distribute in the long term the impact from investment payments on public accounts. Pure concessions are often seen as a viable option for politicians to deliver infrastructure in times of public-finance shortfalls (Greve & Hodge, 2017), as private participation can potentially minimise both on-budget expenditure and on-budget debt under certain conditions[10] (Vining & Boardman, 2008). There are, of course, critical voices arguing that the taxpayer will end up paying much more for something that could be publicly delivered. While this is true when the

[7] A loan from external sources (Foreign Direct Investment) should be considered in the CBA as resources getting in and out of the "society". Ideally the related payments should reduce the investment costs but also reduce the net benefits with the reimbursement of the loans (principal and interests). On the other hand, loans from internal sources are not affecting the "resource accounts" of society.

[8] Public loans are automatically added to public debt, but the assignment of funds from the annual budget are often partly financed through additional public debt emissions. In this sense also such assignment, may be considered a time spread mechanism.

[9] Grants and other types of risk sharing mechanisms from upper-level administrations (e.g. the European Commission) may have a "leverage effect" because they have the potential to unlock greater levels of public- and private-sector resources (DG-IP, 2017). This leverage effect is particularly welcome for bankable projects that address public objectives but that, however, may fail to attract private investment due to macroeconomic constraints, as such constraints have the potential to change the demand risk perception of investors, especially when confidence in the overall economy is low.

[10] The accounting rules in the USA as well as in the European Union are very restrictive with regards to the possibilities to consider PPP loans as off-budget. However, the practice of providing a government balance sheet itself according to internationally accepted accounting standards with the inclusion of PPP debt details on this balance sheet is not particularly common, internationally (Greve & Hodge, 2017).

comparison is made with a similarly performing (in terms of costs and timing) public entity, it is more difficult to accept this negative remark when the private participation entails more efficiency in terms of resources, as the eventual profits for the private partners are money transfers within stakeholders that do not affect socioeconomic efficiency. The key factor for decision makers should be the ability to produce the same benefits with less resources, even if it means public overspending (Hodge, 2004; Hellowell & Vecchi, 2013; Connoly & Wall, 2013). If a PPP solution brings more efficiency, private profitability would essentially become a redistribution issue, which may have political implications, but should not, in principle, prevent opting for it.

In recent decades, DBFMO[11] contracts have been widely used to finance major investments in transport infrastructure, as this type of PPP allows linking payments to the users' ability to pay for infrastructure services (Pagano & Perry, 2008). It is assumed that project's efficiency can raise if private participation gets involved, especially when the public sector lacks expertise (Iossa & Martimort, 2012), despite the additional resources consumed (tendering, procurement and other transaction costs). However, the effects of private participation on project efficiency are difficult to predict or measure in the long run and therefore seldom taken into account in the socioeconomic CBA (Bristow & Nellthorp, 2000). Actually, many researchers and observers have claimed that the use of PPPs may have led to an inefficient allocation of resources for long-term investments and, hence, the public sector would not have really obtained efficient PPPs deals really (Greve & Hodge, 2017; Eurodad, 2018). This can be explained by the private partners' intentions and strategies in financing public infrastructure, which often involve an opportunistic[12] behaviour (Edwards et al., 2004; Shaoul, 2005; Flinder, 2005), as they only pursue to seek profit opportunities rather than thinking about proper project development (Greve & Hodge, 2017). Indeed, although there exists consensus about the fact that some project-linked risks can be better managed[13] by private actors (Forrer et al., 2010), the experience gained from the cumulated use of PPPs in some developed countries suggests that there is always a price to pay (Miranda, 2010), as private finance involves substantial political and democratic costs in terms of freedom to decide on investments by future generations (Flinder, 2005), especially when the private sector gets involved in certain services that "cannot be allowed to fail" (Shaoul, 2003).

What is clear is that the financial burden for the same amount of public investment is higher when channelled through private agents because both the financing costs of the private partner (from loans from either IFIs or commercial banks, even if the final guarantee falls on the GPI), and those arising from technical and legal tasks needed for project finance imply additional costs for the private partner (Engel et al., 2013; Medda et al., 2013). Besides, if the private sector gets

[11] A DBFMO commitment implies for the private partner to design, build, finance, maintain and operate the infrastructure and, once finished the concession period, transfer it to the GPI. It can be considered a financing mechanism that allows the GPI to distribute the financing impact during longer time-spans when there is an effective transfer of the majority of risks to the private partner. Otherwise, the higher amount to be paid is included as debt (discounted future payments) for the GPI.

[12] Opportunism may happen at the moment of the bids, during the execution of the contract and just before its maturity (Williamson, 1976). In long-term concessions involving transport infrastructure provision, a major problem for the GPI is with the opportunistic renegotiation phenomenon, which is the incidence of contract renegotiation shortly after their award (Guasch, 2004; Guasch et al., 2007).

[13] PPPs are often justified on one assumption and one fundamental presumption: the assumption is that in a globalising world –i.e., more integrated, complex and volatile– governments simply may not possess the pre-requisite of knowledge, capacity or managerial skills. The presumption is that the two parties of PPPs can share a common goal, which provides the incentives for the both sides to cooperate, innovate and work collaboratively towards the success of the enterprise (Forrer et al., 2010).

involved in project financing and management, an appropriate equity[14] return should be granted in addition to the reimbursement of the investment. In addition, several factors, such as complications in the land acquisition/expropriation process, the lack of clarity with respect to the legal and regulatory framework or the inexistence of a credible and efficient dispute resolution mechanism, could mean extraordinary costs in the future (Guasch, 2004; Engel et al., 2013). This may lead bidders, in particular those with a low risk profile, to affect the participation in PPPs with a relatively high-risk premium. This explains why institutional investors tend to get involved in these projects one the project is commissioned and operating.

The justification of the PPP formula for major infrastructure must therefore come from a substantial increase in efficiency. This is more obvious when the other main argument for PPPs, their positive effects on public accounts may easily become a form of fiscal illusion, because off-budget loans may represent the same or a higher future liability as if the government had taken up the loans itself (PPIAF, 2009). Maintaining the illusion of reduced public deficit/debt is, however, particularly attractive for "present" decision makers (politicians with a short-term focus rather than public servants), as individuals (voters) are less likely to perceive the project's costs (Coghill & Woodward, 2005; Vining & Boardman, 2008). A main theoretical advantage of PPPs is that private agents usually bear the full lifetime costing of the asset in which they get involved (Debande, 2002) but, in practice, the GPI becomes a partner of last resort of the private sector because it retains ultimate responsibility for service delivery (Grimsey & Lewis, 2004; Yescombe, 2007). Major risks fall, at the end of the day, on the public partner. Moreover, as stated, the private partner expects an equity return, even if it is subject to penalty deductions for substandard service delivery, defined in terms of availability or performance. Under this framework, private finance, in particular when it is seen as a financial transaction in which the private partner undergoes a procurement process similar to the public administration, often represents a "buy now, pay latter" scheme (Flinder, 2005) that does not alter the project's social costs or benefits but simply shifts the GPI's book debt to another off-budget organisation (Vining et al., 2006) that, in practice, takes little risk if there is a final responsibility from the public sector, as it is often the case.

As the proportion of total investment channelled through PPP arrangements grows, more and more of the future budgets of the GPI may be committed (unless the infrastructure is expected to be fully paid by the users), leaving less and less investment funds to the discretion of its decision-makers and reducing their flexibility in the event of budget constraints (Pollock et al., 2001). The introduction of PPPs, whatever the specific model, ties the two parties together through long-term commitments where the eventual payment obligations to the public partner are ahead of other public expenditure priorities (Ball et al., 2001; IPPR, 2004; Shaw, 2004). As mentioned above, this has strong implications for future generations; the selection of a PPP arrangement requires specially robust analysis and justification (ECA, 2018), but also an intergenerational scrutiny of its *financing impact*[15].

[14] Beyond the reimbursement of the principal, the financial return for private agents encompasses the interest on debt, the project's financing costs and a financial compensation for the adopted project risks. The financial rate of return (FRR) showing the project's overall profitability for the private investors, which covers the whole financing package, has to be substantial enough for the SPV to attract the necessary capital from private investors. This implies that the overall expenditure linked to project development is typically higher in PPPs than in traditional contracting-out delivery models in the initial considerations. The financial interest for the GPI could only come from the avoidance of cost overruns and delays.

[15] The concept of *financing impact* refers to the time distribution of the public expenditure that the GPI will have to bear during the project lifecycle as the result of the financial model adopted for infrastructure construction and services delivery. This time series could be expressed in a suitable way to state the impact on future generations. For more details concerning its calculation see *"Key sources of financing and links of cash in/out-flows to obtain the financing impact (FI)"* in Penyalver & Turró (2017:159).

2.2. INTERGENERATIONAL IMPLICATIONS OF FINANCING MAJOR INFRASTRUCTURE PROJECTS

Major infrastructure projects, due to their impact on society's welfare, are decided by the relevant administration or GPI, who also decides how to finance them. In the case of transport, public authorities (taxpayers) are, in general, the main contributors to the funds needed for the investment and, often, for its operation (CODATU, 2009) through public budgets, which feed from general taxation on revenues, property, consumption, etc. and on specific taxes for the transport sector (on fuel, vehicle purchase and ownership, etc.), which, in some cases, are earmarked. Besides taxpayers, beneficiaries[16] (users and non-users) contribute to the transport system income. The level of cost recovery by the users, according to the "user-pays" principle, depends very much on the transport and mobility policy being applied by the government[17]. The options in terms of instruments to sustainably finance major transport projects are multiple (cf. Table VI-1). A main challenge for the GPI is to get access to them and to combine them wisely and fairly (DG-Move, 2018).

Table VI-1. Sources of funds and financing instruments for transport projects

Funding sources / / Financing instruments	Source of funds	Who bears the financing burden?
Grants	Upper-level government	Wider society
Public budget	Taxpayer	GPI society
Earmarked taxes	Specific fund	Specific taxpayers (mostly beneficiaries)
(*) Debt facilities	IFIs, Commercial banks, Institutional investors, Capital markets	Society
Private partners of PPPs	Equity, quasi-equity, loans to private partner or to Special Purpose Vehicle (SPV)	Society/ Beneficiaries
Land value capture mechanisms	Real estate owners	Beneficiaries
Fees (tolls, transport tickets)	Users	Beneficiaries
(**) Versement Transport (France)	Employers	Indirect beneficiaries

(*) This concept refers to the group of borrowing solutions supported by the public budget (taxpayers): debt emission (project bonds and green bonds), long-term loans, short-term credit facilities, etc.

(**) Local tax to finance public transport services levied on the total gross salaries.

Source: adapted from DG-Move, 2018

An adequate blending of funding sources under a long-term financing perspective is key to ensure that the effects of the formula finally adopted for the project will be acceptable. Decision-makers are essentially concerned about their electorate, i.e. individuals belonging to the extant generation, so they will care more about the early benefits of infrastructure investment than the later ones (Penyalver et al., 2017). This is actually what is behind the use of social discount rates in CBA, which considers that present consumers must be compensated for their later consumption. The short-term view of many decision-makers favours spreading out the project's financial burden over long timespans. Besides, as stated, it also favours to share, partially or totally, the project financing burden with private agents through some type of PPP in the case of macroeconomic constraints. This means that, depending on the financing formula finally adopted, the financing provisions linked to the investment might not be aligned with the distribution of the project's benefits that the society "of each moment" obtains along the

[16] The *beneficiaries* concept refers to those people, companies and business activities or entities that will obtain benefits from the presence of public transport infrastructure and the accessibility that it provides (optionally) without necessarily being direct users (DG-Move, 2018).

[17] Adequate infrastructure for mobility is considered central for social inclusion and critical to an individual's capacity to participate and prosper in the modern-day economy (NLC, 2017). As a consequence, the application of the "user-pays" principle, supported by the EU, is seldom observed. In particular, when dealing with urban public transport, which involves complex environmental issues, subsidies are common.

lifecycle of the project. It is indeed usual that the design of the project's financing formula responds more to political, including macroeconomic, constraints than to efficiency or equity considerations (Turró & Penyalver, 2019).

In traditional infrastructure procurement, the actual payments to cover the project costs depend on the financing formula chosen, which may affect taxpayers and/or users of different generations. If transport investment is directly covered by annual budgets, taxpayers will bear the financial burden during the construction period while project effects will benefit individuals that will live in a very distant future. However, if investment is financed through loans or debt emission, the payment schedule will define a very different financial time-profile. Having recourse to private finance may provide certain advantages to decision makers as it can perform for them as a mega credit card (Hodge, 2004), but this involves additional expenditures because private sector participants require high premiums to accept project risk (Vining et al., 2006; Vining & Boardman, 2008). Both the overall expenditure and the distribution of the project's financing burden over time may have a strong influence on the perception of the utility of projects unfolding over long timespans (Penyalver et al., 2017). The intergenerational implications for future contributors of the financial package finally adopted should therefore be carefully analysed using a long-term perspective.

Another key issue that should be tackled is the intergenerational redistributive effects stemming from taxes. The value-added tax (VAT), for instance, which is a turnover tax enforced by a government entity, whether local, regional or national, and levied as a percentage of transactions, but charged only on the final consumption (Lindholm, 1970), may affect the actual burden on the users and taxpayers of specific years. As the VAT paid on transactions from VAT-paying firms prior to the final sale is deductible either from the tax liability or tax base within the current year, it should not entail, a priori, intergenerational redistributive effects. In particular, the effects of VAT linked to the project will be neutral from the perspective of the society as a whole if the GPI resorts to traditional contracting-out mechanisms for infrastructure provision, even though the existence of different levels of governments, some of them VAT recipients and others not, can entail some redistributions within the country where VAT is generated and declared. However, if the GPI resorts to private finance, e.g. through a DBFMO contract, the VAT generated by the paying users (for instance, on tolls[18]) will mean a net income for government (society). The amount to pay in concept of VAT is important in major infrastructure projects, so it is common, for instance, that a concessionaire finances such spending through ad-hoc VAT loans from private banks with the aim of minimising its impact on the accounts of the construction period. These loans are guaranteed by the VAT amounts that the concessionaire will collect from the end users of the facility over the years until the amount paid earlier is fully recovered. In this case, it could involve some intergenerational redistribution of the investment VAT. Profit taxes of the different private stakeholders in the project may also have some redistribution effects among authorities and change over the years. The effects of the financial package should therefore be carefully analysed using a long-term perspective.

[18] When the PPP is based on publicly-paid availability payments, the VAT issues are similar to those of publicly financed projects.

3. METRICS FOR THE ESTIMATION OF THE INTERGENERATIONAL EFFECTS IN THE CONTEXT OF THE ADDED VALUE CALCULATION OF THE DIFFERENT DELIVERY MODELS FOR MAJOR INFRASTRUCTURE PROJECTS

A critical point in the discussion about the assessment of the long-term effects of major investments in transport infrastructure is whether the method of discounting and/or the value of the social discount rate in CBA leads to the right conclusions in terms of efficiency for all the people affected over the project life because, as already explained, CBA looks at actions from the point of view of the "present" society, as discounting is used to transform expected consumption and production of resources into "present values", i.e. values for the society of the moment when the decision is taken. The uncertainty about the future and the innate desire of immediate consumption justify the lower valuation of the project impacts appearing in the years to come. The fairness of such intertemporal approach to the estimation of project efficiency, a critical factor in decision making, is arguable (Penyalver et al., 2017).

On the other hand the efficiency analysis is not considering, at least directly[19], how the project is financed, because CBA is not affected by pure money transfers between users and operators or between them and the government (fees, taxes, etc.), as they do not involve resource modifications. However, there is substantial economic literature pointing out intergenerational equity and fairness issues stemming from transfers between generations linked to financing models (Kotlikoff & Raffelhuschen, 1999; Williamson & Rhodes, 2011). In the transport sector, money flows among stakeholders are actually critical for the financial structuring of major infrastructure projects (Turró, 2004). In this sense, the analysis of intergenerational impact performed through IREM, linking resources and financial flows, goes beyond the classical efficiency analysis and provides a view of the fairness of the actual financial provisions for the project across the various generations affected.

IREM allows us to compare the effects of the project on the different *"annual generations"*, which include people living in the few years before and after the central year defining the generation (Penyalver et al., 2017). The model is based on the time series of the gap between the net socioeconomic benefits and the financial payments for each annual generation[20], which requires the use of both the yearly net socioeconomic benefits obtained from the cost-benefit analysis and the yearly payments made by the various agents participating in the project, ultimately users and taxpayers. The time series obtained indicates the foreseeable differential impacts of the project on future generations. Its analysis allows the assessment of the project's effects on three interlinked dimensions (cf. Table VI-2).

[19] Some financial factors (notably tariffs, tolls and other charges) are affecting demand and the benefits, and in a lesser measure the costs, of the project.

[20] This ad-hoc view of an *"annual generation"* strictly refers to the cohort of individuals living around a central year (the model defines a formula to adequately consider those affected by the project) and allows reflecting the effects of a transport project on overlapping generations.

Table VI-2. Analysis of intergenerational impacts: dimensions and general outlines of IREM outputs

Dimensions of the analysis of intergenerational impacts	IREM indicators	Assessment of IREM outputs
D1. Intergenerational Utility The project's financing formula finally adopted by the government promoting the investment should sustain the welfare of future individuals. This implies positive gaps between net benefits and financial payments (by users and/or taxpayers) for the sets of affected individuals (grouped in annual generations) over the project lifecycle.	$\overline{GAP}$: Average value of the different generational gaps *(GAP_i)* obtained along the project lifespan, expressed in millions of euros (M€)	A $\overline{GAP}<0$ essentially suggests that the project's financing formula has a negative impact for most of the generations affected.
	GUI: The *General Unfairness Indicator ($0 \leq GUI \leq 100\%$)* reflects the intergenerational utility of the project. It represents the rate (%) of overlapped generations enduring financial payments higher than the increase of resources obtained from the project	Low values for *GUI* indicate that the number of annual generations being unfairly treated (paying more than the net benefits they obtain) is small.
D2. Intergenerational Performance The evolution over time of the effects of the project on the concerned annual generations.	*T&S:* Trend and Slope (in grades) of the time series of the generational gaps of the projects. *($-100g \leq T\&S \leq +100g$)*	*T&S>0* means that the value of the successive gaps tends to be more positive or less negative. The higher the value of this indicator the more useful (or less harmful) the project is for future individuals.
D3. Intergenerational Redistribution In projects unfolding over large timespans, redistribution issues may arise if there are significant transfers of the project's financial burden among groups of annual generations.	*IRESI*: The *Intergenerational Redistributive Effects Sharing Index* informs about how redistribution effects are shared among generations over time *($0 \leq IRESI \leq 1.00$)*	*IRESI* tends to 1.00 if the differences between the value of the positive and the negative generational gaps are important, which means that the financing formula is severely biased in favour of certain generations.

Source: Turró & Penyalver, 2019

The IREM's outputs offer a comprehensive picture that allows to label[21] a project in terms of fairness/unfairness from an intergenerational perspective (cf. Table VI-3). The IREM indicators are not adequate, however, to answer the more political issue about the appropriateness or not of making users pay for the investment they benefit from, i.e. the application of the "user-pays" principle. In blending finance the issue of "who pays" is obviously a key factor in the decision about the financial structure to be adopted, but it is not so relevant in intergenerational terms, which are essentially affected by the timing of the users and taxpayers payments of the investment and operation and maintenance of the asset.

Table VI-3. Project Intergenerational Rating Scale

D1. Utility		D2. Performance	D3. Redistribution	Project intergenerational impact	Project Label	
$\overline{GAP}$	*GUI*	*T&S*	*IRESI*			
> 0	≈ 0	> 0	≈ 0	Positive	*fair-balanced*	*BAL*
> 0	Low	> 0	Any	Positive but unbalanced	*fair-unbalanced*	*UNB*
> 0	High	> 0	Low	Positive but unfair	*unfair +*	*UF+*
≈ 0	High	Any	High	Poor and very unfair	*very unfair*	*VUF*
≤ 0	High	< 0	Any	Negative	*regressive*	*RGS*

Source: Turró & Penyalver, 2019

It is in this sense that different blending of public budget assignments and other financing resources will, in general, lead to different time-series of the final financial payments and

[21] A detailed discussion of the different labels that may result from the combinations of the IREM's outputs is shown in Turró & Penyalver (2019).

therefore of the IREM gaps evolution and, as a result, to different values for the various IREM outputs. For instance, financing the public budget contribution to the investment through a project bond or a debt emission with long-term maturity represents delaying the payment of the principal and thus a transfer of most of the investment financing problem to individuals living in a distant future. However, if the project is financed through soft loans[22], the investment impact is distributed over the many generations who must repay them, which typically results in a fairer intergenerational balance. Indeed, the most common financing formulae used for infrastructure projects unfolding over long timespans often misalign the financial provisions affecting the society "of each moment" in relation to the distribution of the net benefits it is expected to obtain (Turró & Penyalver, 2019). As a consequence, even efficient investments could entail severe redistributive effects among generations.

The IREM's outputs are useful to analyse the importance of these effects because they provide metrics on the impacts of any financing solution for infrastructure provision on the various generations that will be affected by the project. The basis for the model is the difference between the monetary payments and the net socioeconomic benefits occurring every year during the project cycle. These payments are the sum of what is actually paid by users (through tolls, fees, etc.) and what the public sector (i.e. taxpayers) must disburse to the financial entities and to private investors having contributed, through loans or other financing mechanisms, to fund the commitments to the project of the involved administrations. In this sense, when the project is conveyed through a private entity, how this entity is funded is irrelevant in intergenerational terms, as what matters is only what users and public administrations pay to compensate it for its financial contribution to the investment and the operation and maintenance.

A key question on the added value of PPPs, as already explained in detail, is whether private participation can deliver infrastructure and offer services at least equivalent in quality to that which could be provided by the public sector through traditional infrastructure procurement, but minimising the overall expenditure, in terms of resources, linked to the project. Indeed, if properly planned, private participation can be useful to introduce solutions that may enhance project design and have an influence on its performance and/or on users' behaviour (e.g., European telepass[23]), which has obvious implications in terms of economic efficiency and may contribute to the financial sustainability of the project as well. Under the "intergenerational approach", this envisaged positive impact of the PPP for the whole society should be both in the short and in the long run.

The aim would be to combine the most efficient solution for project development with a fair distribution of the financial burden to be borne by the successive generations of users and taxpayers concerned. While efficiency is conventionally analysed through CBA, to ensure that the proposed financing structure is acceptable in terms of intergenerational utility, the IREM indicators should show that the PPP arrangement provides an acceptable performance, at least with regards to any possible publicly-managed alternative channelled through conventional procurement contracts. From the intergenerational perspective, the increase/decrease of the average of the IREM gap ($\Delta\overline{GAP}$), in particular, should be considered as a valuable insight on the estimation of the VfM of a PPP.

[22] Loans from public lending institutions –International Financial Institutions (IFIs), national banks, etc.– that offer particularly good conditions in terms of duration, interest rates, grace periods, etc.

[23] The European telepass system or "Telepass EU" is a technical solution that allows an easy and fast passage through toll stations of a number of EU countries. This means socioeconomic benefits in terms of time, fuel consumption, safety, etc., but also higher revenues from users potentially, as this system comes with a number of advantages for customers (rebate scheme, integration of toll data, etc.).

4. PRACTICAL APPLICATION

IREM has been applied to a sample of greenfield investments, carried out in recent decades, aiming at extending the urban public transport (UPT) network of different metropolitan areas. In the UPT sector there is a need for long-term financing to guarantee the financial sustainability of major infrastructure projects, as in the majority of urban areas, at least in the EU, UPT services cannot raise the necessary revenues for full costs recovery from user charges (DG-Move, 2018). The intergenerational approach previously described is thus of particular interest for the UPT sector because most PPP contracts involve compensations, besides the investment, for part of the operation and maintenance (O&M) expenditure[24]. A relevant aspect for project funding is that such public payments are usually quite constant for the investment component and partially related to demand for the O&M part. The IREM gaps should appear, as a consequence, as relatively stable. This means that, a priori, PPPs could be fairer than other options, such as upfront budget contributions or certain types of GPI loans that could represent a heavier burden on specific years[25].

The sample consists of investments in both metro and tramway infrastructure developed through traditional infrastructure procurement mechanisms (TIP scenario). The projects overcame previous tests on efficiency, etc. (cf. Table VI-4). A description of the particularities of these mechanisms for UPT as well as the funding sources and the financing formula actually used for the GPI in each case studio are reproduced next.

Table VI-4. Overview of the cost-benefit analysis (Present Values in M€)

Project code	Type of infrastructure	Year of reference	Project lifespan (including construction)	Benefits for users	Benefits for the whole society	Main investment and Renewals	O&M costs	Economic Rate or Return (ERR)	Benefits-Costs Ratio (5%)
04/008-01	Metro	2008	31	4,984	74.7	2,210	1,484	11.4%	1.37
11/008-01		2008	35	489	0.0	348	153	4.8%	0.98
09/009-01		2009	38	953	6.3	691	126	6.0%	1.17
10/100-02		2010	38	1,768	3.2	1,242	217	6.0%	1.21
11/007-01	Tramway	2007	35	184	0.0	94.9	92.2	4.8%	0.98
12/008-01		2008	34	490	106.4	394	197	5.1%	1.01
13/007-01		2007	26	164	0,0	59.9	61.1	11.1%	1.36
14/100-02		2010	31	57.8	15.0	53.2	14.0	5.7%	1.08
16/009-01		2009	35	947	0,0	518	191	6.0%	1.34

Source: Author

For all these case studies, and for the single purpose of performing a comparative analysis in terms of intergenerational patterns, alternative "PPP scenarios" with common private finance mechanisms has been defined. The objective of this exercise was to perform a comparative analysis of the IREM's outputs from both scenarios to obtain evidence about their respective added value for society in terms of intergenerational redistribution.

[24] Compensations for O&M, in most developed countries with a high car ownership level, must cover more than half of the O&M costs of the UPT system and extend over the whole partnership or concession period. Those related to investment are usually spread over the same period or, alternatively, over a long one.

[25] A particularly dramatic case would be the use of "bullet" loans for which amortization of the principal and even interest are concentrated in the final years of the credit operation. But other particularities of long-term loans, such as long grace periods might also affect intergenerational redistribution.

It is worthwhile to note that UPT fares are kept relatively low for a set of reasons[26] and that the substantial subsidies needed to cover the resulting financial gap may come from different public administrations. While local governments are often the GPI and contribute to both investment and O&M, metropolitan, regional and national bodies are, in many countries, also participating in the financing of the different components of the UPT project. The distribution of subsidies establishes which taxpayers are finally bound to contribute to the project. This is politically very relevant but it is not a factor in intergenerational considerations.

4.1. TIP SCENARIO

In this scenario, the public promoter, a transport authority or a public consortium with responsibilities in UPT services delivery (GPI), deals with external firms for infrastructure provision and maintenance services. These firms are typically private actors (infrastructure builders) providing services through tendering/awarding processes. The selected bidder (main contractor) executes and delivers a project according to the GPI's plan, which finally specifies the type and quality of the works to be provided. Once the construction is complete, the infrastructure becomes a part of the public transport system, which is often managed, at local level, by public transport operators[27] with the aim of providing efficient and reliable UPT services in the market. Nonetheless, it is the GPI who takes the full responsibility for the financial package for project development, which typically consists of public budget assignments and debt instruments[28] that essentially represent a postponement of the budget payments (cf. Table VI-5).

Table VI-5. TIP scenario: Financial structures of the UPT projects, from present values discounted at 5%

CASE STUDY			FUNDING SOURCES					FINANCING		
Project code	Type of UPT project	Delivery model	EU grants	GPI budgetary contributions (to Capex)	Users Revenues	GPI subsidies (to Opex)	Private Finance	From additional public debt	Long-term loans from IFIs to the GPI	Loans from commercial banks to the GPI
04/008-01	Metro	Contracting-out mechanisms	30.9%	0.0%	46.6%	0.0%	0.0%	4.7%	17.8%	0.0%
11/008-01			7.8%	0.0%	27.7%	1.5%	0.0%	16.5%	36.2%	10.3%
09/009-01			0.3%	0.0%	14.3%	1.9%	0.0%	0.0%	66.7%	16.9%
10/100-02			0.0%	0.0%	17.7%	1.6%	0.0%	0.0%	80.7%	0.0%
11/007-01	Tramway		0.0%	0.0%	5.6%	41.5%	0.0%	0.0%	28.2%	24.7%
12/008-01			1.0%	32.8%	5.9%	30.1%	0.0%	0.0%	30.2%	0.0%
13/007-01			21.7%	0.0%	35.3%	12.2%	0.0%	0.0%	30.8%	0.0%
14/100-02			40.9%	2.4%	11.8%	0.0%	0.0%	0.0%	47.3%	0.0%
16/009-01			2.8%	0.0%	30.0%	0.0%	0.0%	49.9%	17.3%	0.0%

Source: Author's database

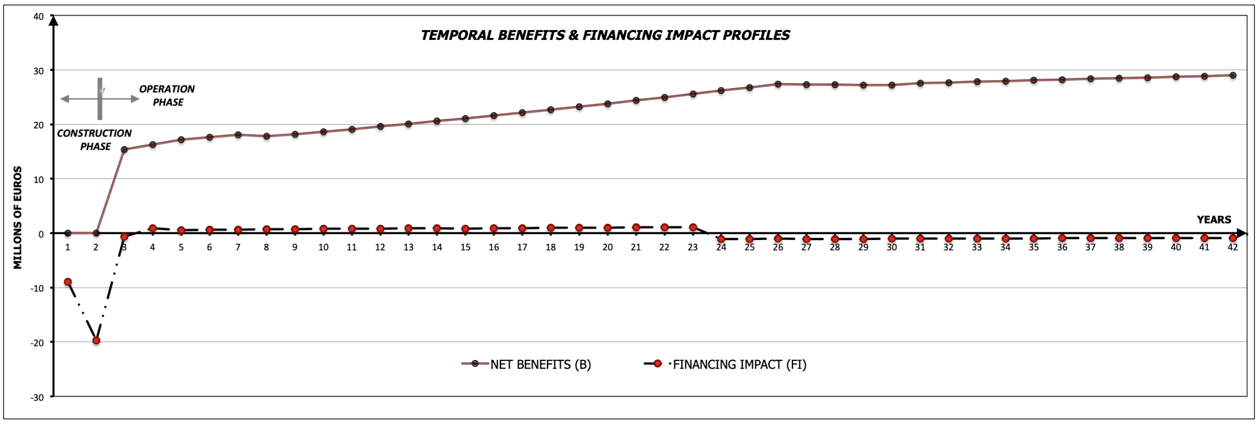
[26] The reasons for limiting the contribution of users are to favour the diversion from cars to UPT to reduce non-internalised externalities of urban traffic and to comply with its social role as provider of basic accessibility to citizens (DG-Move, 2018).

[27] They are typically 100% public services companies or public holdings that may belong to public shareholders or to mixed public-private ventures.

[28] GPIs have different borrowing options from IFIs and commercial banks and, in some cases, they may emit project bonds that, in some cases, could have fiscal incentives. Loans are common for infrastructure provision. For the purchase of mobile assets (e.g., trains, trams, buses), other options, such as leasing, are often used.

In the sample, government borrowing, through long-term loans from both IFIs and commercial banks, is the most common option for financing the main investment, though a number of cases count on higher level authorities, including the EU, to provide grants that reduce the GPI's investment needs. Budgetary contributions for capital expenditure (Capex) during the construction period tend to be relatively small. On the other hand, public debt emissions are seldom used to finance UPT investments. Once the project is in operation, as fare revenues are, in most cases, insufficient to cover O&M costs, the financial sustainability of the project requires also subsidies. In this sense, Figure VI-1 below offers a good picture on how the financial burden stemming from the most common financing option of the TIP scenario is distributed over the years.

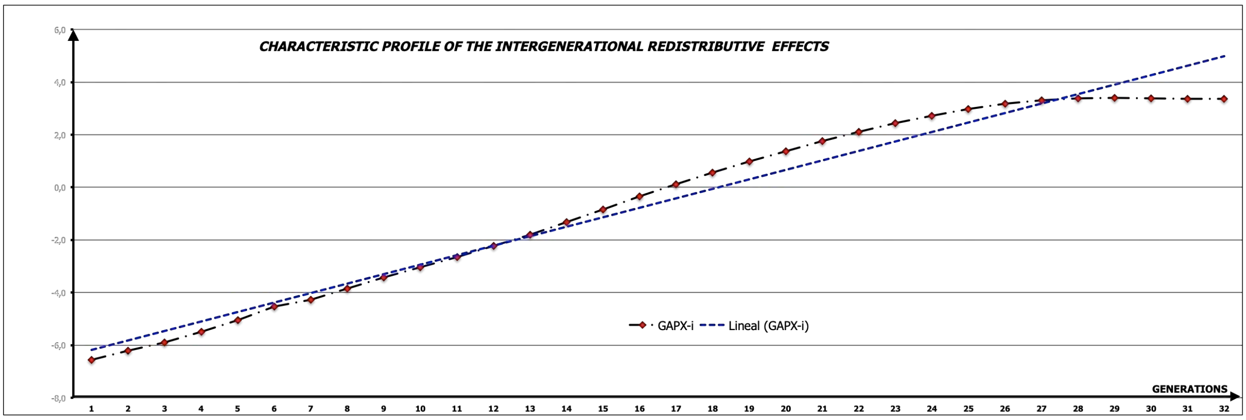
Figure VI-1. Socioeconomic and financial time-profiles of the "13/007-01" project



Source: Author

Figure VI-1 is a graphic representation of the time-profiles of the socioeconomic net benefits *(B)* and the financing impact *(FI)* of the project with code "13/007-01". In this case, the main investment was financed with funds from EU grants (41.3% on the estimated financial gap of the main investment) and from a soft loan with 20 years maturity and 2 years of grace period. As can be observed, this option allowed the GPI to spread the investment burden across the many generations benefiting from the project's effects, in the short and in the long run. As a consequence, the financing formula is fairly progressive, as intergenerational redistribution is unimportant *(IRESI= 0.06)* and the evolution over time of the project's socioeconomic effects with regards to the financial charges to be borne by the future generations concerned is soundly positive *(T&S= +18.6g)*. Besides, *GUI=0%* in this case, meaning that the IREM gaps will always be positive during the project lifecycle (cf. Figure VI-2).

Figure VI-2. Time profile of the generational redistributive impact of the project with code "13/007-01"



Source: Author

Table VI-6 shows the results of the analysis of the intergenerational impact performed for the whole sample. Overall, the intergenerational redistributive effects appear as rather unimportant *($IRESI_{average}=0.11$)* and the evolution over time of the projects' effects on the concerned generations is positive *($T\&S_{average}=+54.9g$)*, which means that the financing formula is fairly progressive, as it shares the financial burden over the years according to the distribution of the project's net benefits. On the other hand, most generations obtain positive gaps *($GUI_{average}<13\%$)*, although some exceptions exist *($GUI_{sd}=17.2$)*.

As a result, the overall intergenerational impact of the UPT projects under the TIP scenario appears as positive but unbalanced *("UNB")*. The small sample size prevents, however, obtaining well-founded general conclusions on the different UPT infrastructure types.

Table VI-6. IREM's outcomes by type of project (TIP scenario)

Type of infrastructure	Sample Size (N)	***GUI***		***Trend & Slope (T&S)***		***IRESI***	
		average	sd	average	sd	average	sd
Total sample	**9**	**12.2%**	**17.2**	**+54.9g**	**33.7**	**0.11**	**0.20**
Metro	4	12.0%	14.1	+80.0g	23.2	0.01	0.00
Tramway	5	12.4%	21.1	+34.9g	29.3	0.19	0.25

Source: Author's database

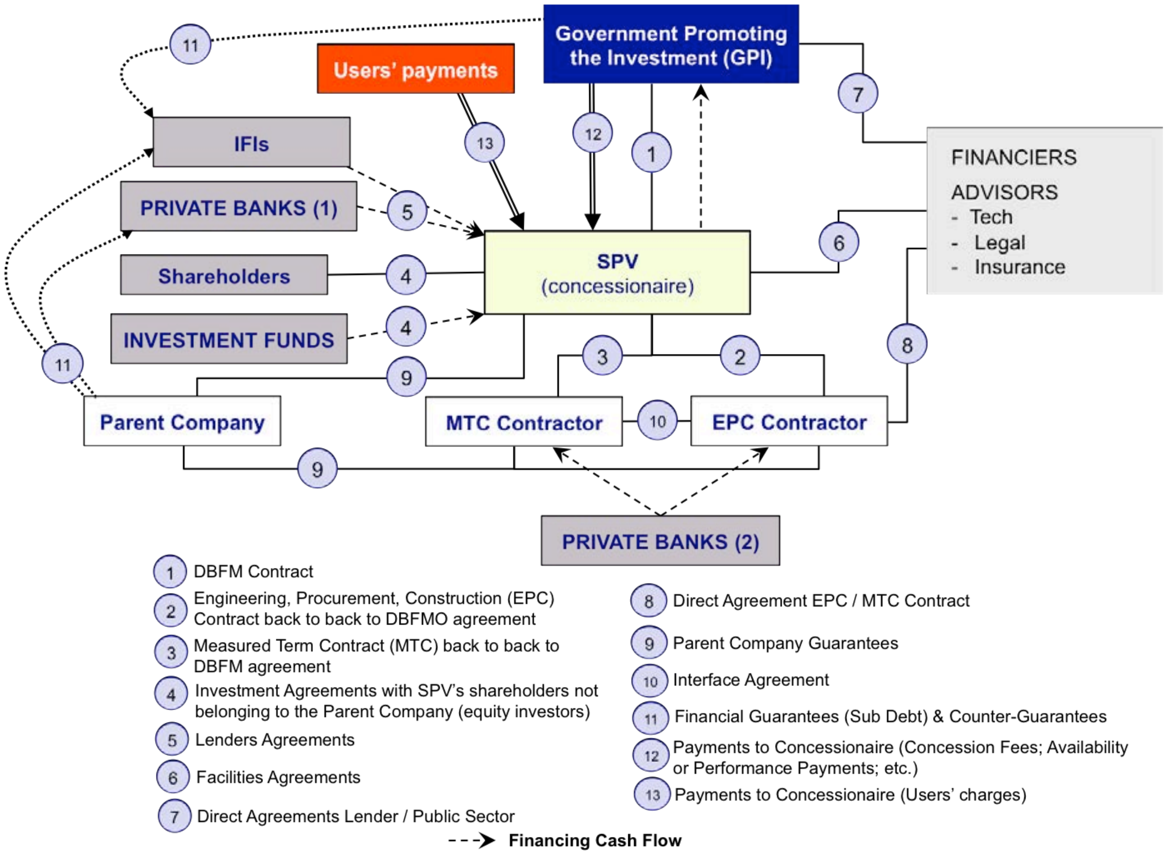
4.2. PPP SCENARIO

In this scenario, it is assumed that private actors can deliver infrastructure and offer UPT services equivalent in quality to those that can be provided by the public sector in the TIP scenario if they get involved in project financing and management through a long-term agreement, such a DBFMO contract[29]. The private initiative is expected to be more efficient and avoid cost overruns that are quite common in TPI projects. On the other hand, PPP arrangements are commonly used by public authorities to attract private investment to UPT infrastructure development. The private partner (a concessionaire in many cases) typically manages all aspects of the project, channelling its participation in the PPP through a Special Purpose Vehicle (SPV), which is a legal structure especially created to take the project risk (cf. Figure VI-3). This investment vehicle is designed to reduce exposure for the larger parent organisations that are usually providing the equity and quasi-equity components of the financing structure but do not wish to provide corporate guarantees (Ye, 2008; Regan et al., 2017). The SPV assumes, however, the responsibility to finance the main investment (infrastructure & rolling stock) and, after completing the project construction, to cover the operation and maintenance costs stemming from the project.

[29] This type of contract allows: 1) to distribute the impact of the capital expenditure in infrastructure on public accounts in the long-term, which usually implies the GPI to get involved in the financing commitments between the sponsor (concessionaire) and financial institutions., 2) to prevent both eventual cost overruns and delays in infrastructure delivery for the public sector, which can be achieve through the right schemes of risks allocation., and 3) to ensure UPT quality service, as PPP arrangements can foresee penalties upon income when private operators are not complying with the agreed or if they are not able to achieve certain targets, usually related to the number of users served. Further, a PPP with the right incentives might contribute to increase demand, even if the private partner has very limited leeway on tariffs.

Only a part of the funds delivered by the SPV for Capex comes from the shareholders' share capital[30] (equity). Traditionally, IFIs and commercial banks provide the bigger part of the funds needed by the SPV for project development (Regan et al., 2017). These loans, although finally secured by the commitment of the GPI to fund the SPV, are bound by higher interest rates than the direct loans to the GPI because the SPV will require some compensation for this task (financing intermediation) and the risks borne. This additional cost may only be justified by the reduced risk of cost overruns of the SPV and, more arguably, by the lower immediate impact on public deficit and debt.

Figure VI-3. Outline of contracts and financing cash-flows in a DBFMO agreement



Source: Author

As already mentioned, the user revenues of a UPT project are, in general, in contrast with other types of public concessions such as toll motorways, insufficient to cover even the O&M costs and it is common that new investments entail an increase in the deficit of the UPT system. The GPI will thus have to establish additional compensations (fees) for the SPV based on availability or other supply considerations. They represent a continuous public support during the whole lifecycle of UPT projects that must be incorporated in the design of any envisaged PPP. Such support must end up compensating the private partner both for her investment and for the foreseen gap between the user payments (through a pre-specified mechanism, particularly complex when there exists an integrated tariff system) and the expected O&M costs. Here again the use of a PPP arrangement should be justified by the lower costs, at least in terms of resources, of the operation by a privately managed SPV.

[30] A common relation between equity from shareholders and debt is 25:75 (equity:debt).

Private actors will require compensation for both their financing intermediation and the project risks they assume. For the first aspect, the interest rate adopted in the case studies for private actors has been increased in 200 basic points[31] to the rate applied to the public sector in the TIP scenario. In addition, with the aim of taking into account the eventual increase in efficiency required to the private participation with regard to the TIP scenario, it also includes a 25%[32] cost reduction in both infrastructure construction and UPT services provision (cf. Table VI-7). Besides, the financing formula also includes a 5% raise in revenues from UPT users[33].

Table VI-7. PPP scenario: Financing formulae referred to the GPI (values referred to the concession period)

CASE STUDY			FUNDING SOURCES					CONCESSION DATA			
Project code	Delivery model	Project lifespan (years)	EU Grants	GPI budgetary contributions (to Capex)	Users Revenues	GPI subsidies (to Opex)	Private Finance	Concession timespan (years)	Construction Period (years)	FRR – SPV (*)	Payback – SPV (years)
04/008-01	Concession contract (PPP/DBFMO)	31	24.6%	0.0%	30.8%	28.4%	16.3%	30	9	10.9%	14.7
11/008-01		35	4.1%	0.0%	12.7%	57.7%	25.4%	30	4	10.8%	10.8
09/009-01		38	0.1%	0.0%	5.2%	65.5%	29.2%	30	7	10.6%	12.2
10/100-02		38	0.0%	0.0%	5.6%	67.7%	26.7%	30	7	10.7%	12.0
11/007-01		35	0.0%	0.0%	2.1%	76.4%	21.4%	20	3	10.9%	9.3
12/008-01		34	0.5%	0.0%	1.8%	74.5%	23.2%	20	4	10.8%	10.1
13/007-01		26	15.6%	0.0%	20.6%	47.2%	16.6%	20	2	10.7%	9.4
14/100-02		31	22.0%	0.0%	4.3%	54.6%	19.2%	20	3	10.9%	9.6
16/009-01		35	1.5%	0.0%	8.7%	63.7%	26.1%	20	5	10.8%	10.6

(*) The financial rate or return (FRR) corresponds to the project's overall profitability for the private investors.
Source: Author

After the concession period, the SPV delivers the assets (metro or tramway infrastructure, and rolling stock) to the corresponding GPI ensuring optimal conditions of use, but without the right to any compensation. From that moment, the GPI may opt between another concession contract to manage these assets or contracting-out such services, which is the option chosen for this exercise, where, in addition, exploitation conditions remain without changes after the concession period. On the other hand, yearly public subsidies to Opex have been calculated for the different financing formulae seeking to both ensure the financial sustainability of the project and offer a market-rate-of-return for private investors, as the expected (financial) returns are key for the concessionaire to obtain financing from the banks. It is assumed that private investors will only participate in UPT financing if the project shows a good financial pay-off and they have sufficient guarantees of repayment. Such guarantees will end up coming from the commitment of payment, in various forms (e.g. credit guarantees) given by the GPI. In this sense the

[31] Input obtained taking into account the financial hypothesis for senior debt of a number of DBFMO contracts of the Government of Andalusia.

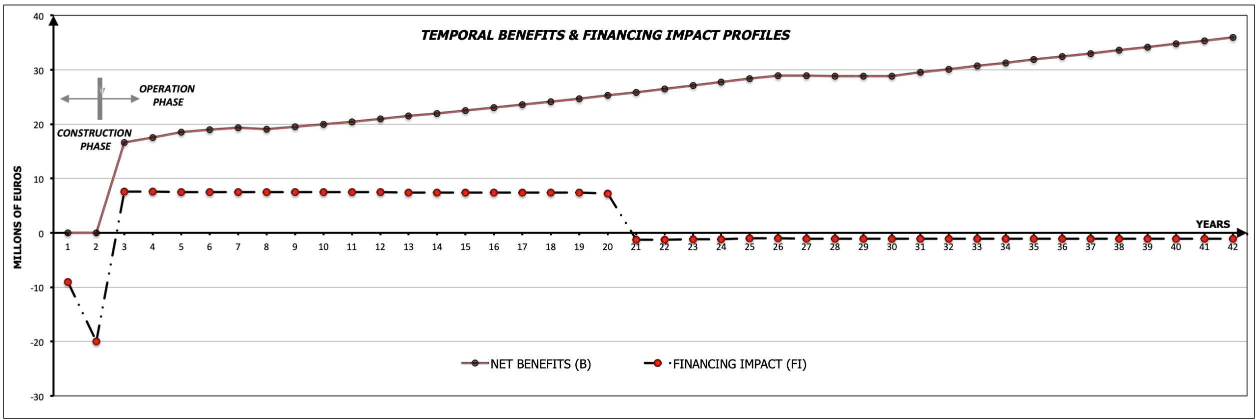
[32] At least in the EU, there is a lack of evidence suggesting that PPPs have succeed delivering transport infrastructure projects more efficiently than the public sector through conventional procurement mechanisms. Indeed, authors agree that the public sector can manage the project's risks efficiently and effectively, in similar conditions to the private sector, if it counts on both sufficient expertise and resources, which is an acceptable premise, particularly for developed countries with highly qualified public officials. Nonetheless, for the exclusive purpose of this exercise, it has been used this percentage of cost reduction, which responds to the average drop in award prices with regard to tendering prices for infrastructure construction through traditional public procurement. Our estimate has been obtained in the report *"El Sector de la Construcció Catalunya 2016. Previsions 2017"*, published online by the Cambra Oficial Contractistes d'Obres de Catalunya.

[33] In general, additional income with regards to the TIP scenario might come from a raise in demand, from increased fees for services to users (Eurodad, 2018) or both. Nonetheless, this raise in revenues does not have an impact in the analysis of intergenerational impact because, in the UPT sector, usually, there is a financial gap that, if not covered with additional revenues from users, it will have to be compensated by the taxpayer through public subsidies.

concessionaire acts as financial intermediary[34] to obtain the money for construction, which means an additional step in the guarantees scheme.

The socioeconomic and financial time-profiles obtained for the project with code “13/007-01” may be considered representative of the PPP scenario (cf. Figure VI-4). The financing structure envisaged replicates, with small variations, the solution previously described. It incorporates the same amount of EU grant money and assumes that private financing[35] is channelled through a concession contract limited to 20 years, which explains the abrupt change in the financing impact profile from year 21.

Figure VI-4. Socioeconomic and financial time-profiles of the project with code “13/007-01” (PPP scenario)



Source: Author

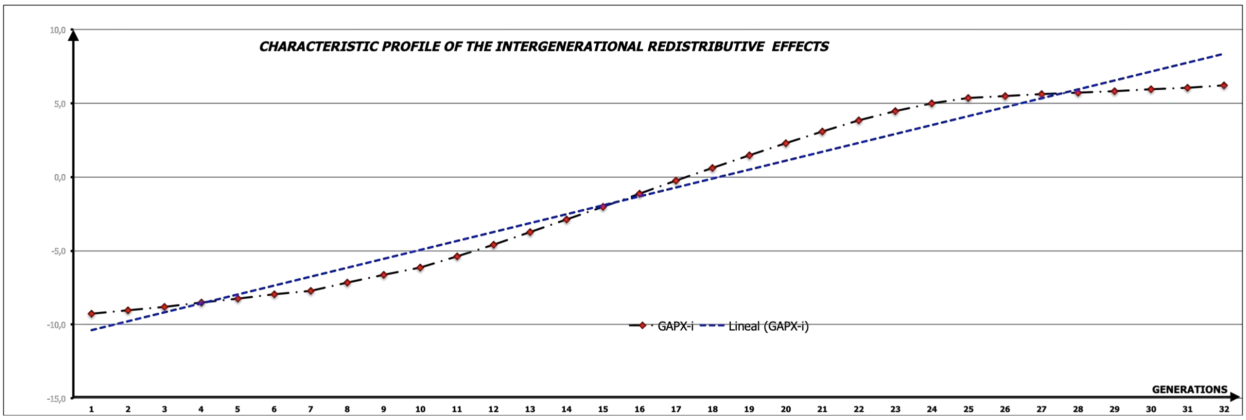
During the concession period, the GPI pays annually a pre-established amount[36] to the SPV in form of availability payments that would encompass investment repayment and other financial compensations to the concessionaire for its role in project management and financing. This solution would allow the GPI to spread the investment burden over a long period (cf. Figure VI-5). Compared with the TIP scenario, the intergenerational redistribution is even of lesser value *(IRESI= 0.03)*, while the project intergenerational performance is even more positive for the concerned generations *(T&S= +34.6g)*. Moreover, as will be seen, $\Delta\overline{GAP} \approx 0$, meaning that in this particular case the increase in public expenditure is unimportant for the many generations affected. Thus, it could be argued that the *Value for Money* component related to intergenerational redistribution would be greater when the GPI, instead of managing the UPT infrastructure through the traditional procurement system, uses this particular delivery option (DBFMO contract). This should not be taken, however, as a general conclusion, because it is based on estimates that are considered adequate, but not necessarily real.

[34] For the analysis of intergenerational impact, credits from IFIs and commercial lenders to concessionaires are not directly accounted but indirectly, including an equity return for private agents, as the financing structure is referred to the public promoter (GPI).

[35] A main assumption is that the projects of the sample, as defined here, are “bankable”, meaning that the SPV will be able to find sufficient funds to carry out the main investment from IFIs and/or commercial banks and equity investors. In this sense, in general, the financial model of the PPP scenario is leveraged at 70%, with financing coming from miniperm (bridge loans for the construction period) and senior debt (loans from both IFIs and commercial banks in 50% proportion) with 17 years maturity from project commissioning in this particular case.

[36] The financial model used for the PPP scenario includes estimation on the additional expenditure to be borne by the private partner. This expenditure has been calculated for the SPV taking into account: 1) financial needs for SPV establishment (e.g., initial treasury of the SPV, legal reserves, guarantees, etc.), estimated at 1% of the investment during the first year; 2) initial costs of the SPV (structure costs, facilities and equipment, etc.), estimated at 2-3% of the capital annual expenditure during the construction period; and 3) operating costs of the SPV from project commissioning, estimated at 10% of the yearly operating income. Such estimations are based on information included in contract dossiers that have been obtained for this research, including those from the Government of Andalusia previously mentioned.

Figure VI-5. Time profile of the generational redistributive impact of the project with code "13/007-01" (PPP scenario)



Source: Author

Table VI-8 shows the results of the statistical analysis of the intergenerational impact for the PPP scenario for the two sets of projects. The evolution over time of the projects effects on the concerned generations is soundly positive for both samples *($T\&S_{average}$* between *50* and *86g)*, which means that the PPP financing formula distributes smoothly the impact of the capital expenditure in the long-term. On the other hand, the intergenerational redistributive effects remain low *($IRESI_{average}$* between *0.08* and *0.15)*. Nonetheless, a significant number of the annual generations end up adversely affected under this financing mechanism in both sub-samples, with most[37] projects with *GUI* between *40* and *50%*. Thus, overall, the projects' intergenerational impact under the PPP scenario should be labelled as positive but unfair *(UF+)*.

Table VI-8. IREM's outcomes by type of project (PPP scenario)

Type of infrastructure	GUI		Trend & Slope (T&S)		IRESI	
	average (*)	sd (*)	average	sd	average	sd
Total sample	**46.7%**	**6.3**	**+65.8g**	**29.5**	**0.12**	**0.09**
Metro	50.0%	2.3	+85.5g	15.5	0.08	0.01
Tramway	44.2%	7.6	+50.1g	29.4	0.15	0.11

(*) Atypical values (statistical outliers) have not been included in this analysis.

Source: Author

4.3. COMPARATIVE ANALYSIS

The analyses of the intergenerational impact performed have provided insights concerning the overall performance of the two alternative financing mechanisms, here named as TPI and PPP respectively.

[37] As shown in Table VI-9, the projects with code "04/008-01" and "13/007-01" offer atypical values in terms of intergenerational utility *(GUI=0%)* with regards to the rest of the projects in the sample, even though private participation implies in both cases a meaningful increase in the expenditure linked to the project, especially from its commissioning. This is due to the importance of the estimated socioeconomic benefits stemming from these projects, of high economic efficiency *(ERR>11%)*. These high benefits ensure that no annual generational has a negative gap. As a consequence, the values of *GUI* obtained for these two projects have been considered outliers and excluded from the statistical analysis.

At first glance, the one based on traditional infrastructure procurement, i.e. publicly financed, appears as more convenient for the successive generations concerned than the one based on private participation in project financing and management through long-term concessions, mainly because PPPs are a more expensive method of financing. As can be observed, in the TIP scenario there are few generations enduring negative gaps in both sub-samples *(*$GUI_{average}$*=7.7%,* excluded the outlier value of the *GUI* obtained for the project with code "11/007-01*)*. Besides, there are not intergenerational redistribution issues *(*$IRESI_{average}$*=0.11)* and the financing formula results fairly progressive *(T&S = +54.9g)*. Nonetheless, the traditional financing mechanism may also lead to controversial[38] outcomes in term of project intergenerational impact, as shown by the IREM's outputs obtained for the project with code "11/007-01" (cf. Table VI-9). Moreover, the collected evidence actually suggests that such intergenerational performance will be better under the alternative financing formula based on PPP agreements.

Table VI-9. Comparative analysis of the IREM's outputs from TIP and PPP scenarios

Project code	Type of infrastructure	TIP Scenario				PPP Scenario				$\Delta\overline{GAP}$
		$\overline{GAP}$	*GUI*	*T&S*	*IRESI*	$\overline{GAP}$	*GUI*	*T&S*	*IRESI*	
04/008-01	Metro	473.8 M€	0.0%	+91.0g	0.01	397.9 M€	0.0%	+93.4g	0.09	< 0
11/008-01		31.1 M€	0.0%	+45.5g	0.01	13.9 M€	52.3%	+62.6g	0.08	< 0
09/009-01		105.6 M€	20.5%	+88.1g	0.01	70.2 M€	50.0%	+90.0g	0.09	< 0
10/100-02		270.5 M€	27.3%	+95.5g	0.01	188.9 M€	47.7%	+96.1g	0.07	< 0
11/007-01	Tramway	−0.10 M€	48.6%	+22.7g	0.10	−3.90 M€	54.1%	+38.4g	0.14	< 0
12/008-01		18.5 M€	13.6%	+52.2g	0.14	1.4 M€	45.5%	+72.7g	0.14	< 0
13/007-01		22.5 M€	0.0%	+18.4g	0.06	21.2 M€	0.0%	+34.6g	0.03	< 0
14/100-02		5.2 M€	0.0%	+4.1g	0.63	2.2 M€	36.4%	+16.7g	0.33	< 0
16/009-01		79.1 M€	0.0%	+76.9g	0.04	53.2 M€	40.9%	+88.1g	0.11	< 0

Source: Author

Indeed, a more detailed analysis of the IREM's outputs shown above shows that private participation, under the envisaged conditions, may succeed in enhancing the project's performance from the intergenerational perspective. This is due to the continuity in the distribution of the financial charges that is a logical set up in a PPP scenario. In this sense, PPP arrangements appear as more convenient to ensure equity for future individuals in comparison with the TPI scenario ($T\&S_{average}$*=+65.8g vs. +54.9g,* respectively), but at the expense of an increase in the number of generations enduring negative gaps ($\Delta\, GUI_{average}$*=+24.1%*). Nevertheless, it is worth noting that, ex ante, this "collateral issue" of PPPs will not have a meaningful impact in terms of intergenerational utility for projects of high socioeconomic profitability.

[38] The project's financial structure may be controversial if *GUI* is high while the evolution over time of the project's effects on the concerned generations is fairly progressive and redistribution issues may be disregarded (high *T&S* and low *IRESI* respectively). In these situations, analysts should first look closely at the value of the $\overline{GAP}$, which is a key indicator on the project's intergenerational utility.

5. CONCLUSIONS

This paper shows that decision makers on major infrastructure projects, besides the usual concerns about efficiency and specific policies on redistribution that are not addressed in CBA, should take into account the effects of the project on the successive generations of individuals affected.

The most common financing formulae used for infrastructure projects unfolding over long timespans often misalign the financial provisions linked to the investment in relation to the distribution of the project related benefits that the society "of each moment" experiences. As a consequence, even efficient investments could entail severe redistributive effects among generations. To analyse these effects, the net benefits for specific generations must be compared with the corresponding money paid by the users of the infrastructure and by the taxpayers for the part that users do not cover. The taxpayers' contribution is channelled through public budgets and, in general, major projects developed through traditional public procurement mechanisms are financed through loans or other debt instruments, including public debt issues, that postpone such contribution. The actual amounts to be paid by taxpayers on specific years depend, therefore, on the financing structure adopted. When the project is conveyed through a private entity, its funding is irrelevant in intergenerational terms, as what matters is only what users and public administrations pay to compensate it for its financial contribution to the investment and the operation and maintenance. The annual financial flows to be compared to the annual net socioeconomic benefits of the project are what is actually paid as tolls, fees, etc. and what the public sector must disburse to the private partner or to the financial entities having contributed to fund the commitments to the project of the involved administrations.

The former analysis can be performed using the *Intergenerational Redistributive Effects Model* (IREM). The model has actually been applied to a sample of investments in urban public transport (UPT) infrastructure formed by greenfield projects of tramway and metro executed in recent decades with the aim of developing the UPT network of different metropolitan areas. The purpose of this effort has been to gain knowledge on the added value that could be obtained potentially from private participation in project financing and management with regards to UPT publicly managed infrastructure-solutions, developed through conventional public procurement.

In the practical exercise carried out in this paper, a main hypothesis is that private participation can deliver infrastructure and offer services at least equivalent in quality to those provided by the public sector through traditional infrastructure procurement, but with better outcomes in terms of both project costs, at least in terms of resources, and intergenerational effects. In this sense, the pattern found in terms of intergenerational performance confirms that, if private actors get involved in project management and financing, the evolution over time of the project's socioeconomic effects with regards to the financial charges to be borne by the future generations entail a more equitable situation than certain financial formulae used for purely public projects.

In short, the IREM results show that public-private partnerships, although often entailing a substantial increase of the public expenditure linked to these projects compared to conventional procurement mechanisms, are typically better in terms of intergenerational fairness. This conclusion cannot be extended to all PPPs, as it depends on the alternative public sector funding, but it is a strong argument in favour of including in the *Value for Money* analysis of PPPs, besides the standard efficiency and financial considerations, an analysis of the intergenerational effects of the different procurement options and to compare these effects with those of the purely public financing alternative.

6. REFERENCES

- Akintoye, A. et al., 2003. Achieving best value in private finance initiative project procurement. Construction Management and Economics, 21(5), pp.461-470.
- Ansar, A., Flyvbjerg, B., Budzier, A. & Lunn, D., 2016. Does infrastructure investment led to economic growth? Evidence from China. Oxford Review of Economic Policy, 32(3), pp.360-390.
- Ball, R., Heafy, M. & King, D., 2001. The Private Finance Initiative: a good deal for the public purse or a drain on future generations. Policy & Politics, 29(1), pp.95-108.
- Boardman, A.E., Greenberg, D.H., Vining, A.R. & Weimer, D.L., 2017. Cost-benefit analysis: concepts and practice. Cambridge University Press.
- Boardman, A. & Vining, A., 2010. Assessing the economic worth of public–private partnerships. In G. Hodge, A. Boardman, and C. Greve, (eds.). In International Handbook on Public–Private Partnerships. Cheltenham: Edward Elgar.
- Bristow, A.L. & Nellthorp, J., 2000. Transport Project Appraisal in the European Union. Transport Policy, 7, pp.51-60.
- Bryson, J.M., Crosby, B.C. & Stone, M.M., 2006. The Design and Implementation of Cross-Sector Collaborations: Propositions from the Literature. Public Administration Review (Special Issue), 66, pp.44-55.
- Burger, P. & Hawkesworth, I., 2011. How to Attain Value for Money: Comparing PPP and Tradtional Infrastructure Public Procurement. OECD Journal of Budgeting, 1, pp.1-56.
- CODATU, 2009. Who Pays what for Urban Transport? Handbook of Good Practices. Mercues.
- Coghill, K. & Woodward, D., 2005. Political issues of public-private partnerships. In G. Hodge & C. Greve (Eds). The challenge of public-private partnerships: Learning from international experience. Cheltenham, UK: Edward Elgar. pp.81-94.
- Connoly, C. & Wall, T., 2013. The impact of the global financial crisis on public–private partnerships: A UK perspective. In C. Greve and G. Hodge (eds). In Rethinking Public–Private Partnerships: Strategies for Turbulent Times. Oxford: Routledge. p.384.
- Debande, O., 2002. Private Financing of Transport Infrastructure: An Assessment of the UK Experience. Journal of Transport Economics and Policy, 36 (3), pp.355-387.
- DG-IP, 2017. Financial Instruments: defining the rationale for triggering their use. (Study PE 603.787; http://www.europarl.europa.eu/supporting-analyses). Brussels: Directorate General for Internal Policies of the Union. Policy Department for Budgetary Affairs.
- DG-Move, 2018. Pilot Project Study on Innovative Ways of Sustainable Financing Urban Public Transport. Final Report. Brussels: European Commission. Directorate General of Mobility and Transport.
- DG-Regio, 2015. Guide to Cost-Benefit Analysis of Infestment Projects. Economic appraisal tool for Cohesion Policy 2014-2020. Brussels, Belgium: Directorate-General for Regional and Urban Policy of the European Union.
- Diamond, J., 2005. Establishing a performance management framework for government. Presupuesto y Gasto Público, 40, pp.159-183.
- Eadie, R., Millar, P. & Toner, L., 2013. "Public private partnerships, reevaluating value for money. International Journal of Procurement Management, 6(2), pp.152-169.
- ECA, 2018. Public Private Partnerships in the EU: Widespread shortcomings and limited benefits. Special Report. Luxembourg: European Court of Auditors.
- Edwards, P., Shaoul, J., Stafford, A. & Arblaster, L., 2004. Evaluating the Operation of PFI in Roads and Hospitals. London: Certified Accountants Education Trust.
- Eichengreen, B., 1995. Financing infrastructure in developing countries: lessons from the railway age. The World Bank Research Observer, 10(1), pp.75-91.
- Engel, E., Fischer, R. & & Galetovic, A., 2013. The basic public finance of public–private partnerships. Journal of the European Economic Association, 11(1), pp.83-111.
- EPEC, 2011. The Non-Financial Benefits of PPPs. A Review of Concepts and Methodology. European PPP Expertise Centre. Luxembourg. Available online at: http://www.eib.org/epec
- Eurodad, 2018. Public-Private Partnerships. Global Campaign Manifesto. European Network on Debt and Development. Brussels, Belgium. Available online at: https://eurodad.org/PPPs-Manifesto
- Fitzgerald, P., 2004. Review of Partnerships Victoria Provided Infrastructure. Final Report to the Treasurer. Melbourne (Australia): Growth Solutions Group.

- Flinder, M., 2005. The Politics of Public-Private Partnerships. The British Journal of Politics and International Relations, 7(2), pp.215-239.
- Flyvbjerg, B., 2005. Measuring inaccuracy in travel demand forecasting: methodological considerations regarding ramp up and sampling. Transportation Research Part A, 39, pp.522-530.
- Flyvbjerg, et al., 2018. Five things you should know about cost overrun. Transportation Research Part A: Policy and Practice, 118, pp.174-190.
- Forrer, J., Kee, J.E., Newcomer, K.E. & Boyer, E., 2010. Public–private partnerships and the public accountability question. Public Administration Review, 70(3), pp.475-484.
- Gollier, C., 2011. Pricing the future: The economics of discounting and sustainable development. Princeton University Press.
- Greve, C. & Hodge, G.A., 2017. Private Finance: What Problems Does It Solve, and How Well? The Oxford Handbook of Megaproject Management.
- Grimsey, D. & Lewis, M.K., 2004. Public–Private Partnerships: The Worldwide Revolution in Infrastructure Provision and Project Finance. Cheltenham: UK: Edward Elgar Publishing.
- Guasch, J.L., 2004. Granting and renegotiating infrastructure concessions: doing it right. World Bank Publications.
- Guasch, J.L.; Laffont, J.J.; Straub, S., 2007. Concessions of infrastructure in Latin America: Government-led renegotiation. Journal of Applied Economics, 22, pp.1267-1294.
- Hart, O., 2002. Incomplete Contracts and Public Ownership: Remarks and an Application to Public-Private Partnerships. CMPO Working Paper Series No. 03/061 (Cambridge, MA: Harvard University).
- Hellowell, M. & Vecchi, V., 2013. What return for risk? The price of equity capital in public–private Partnerships. C. Greve and G. Hodge (eds.). In Rethinking Public–Private Partnerships: Strategies for Turbulent Times. Oxford: Routledge.
- Hodge, G.A., 2004. The trouble with public–private partnerships. The Age.
- Hodge, G.A. & Greeve, C., 2009. PPPs: The passage of time permits a sober reflection. Economic Affairs, 29(1), pp.33-39.
- Iossa, E. & Martimort, D., 2012. Risk allocation and the costs and benefits of public-private partnerships. RAND Journal of Economics, 43(3), pp.442-474.
- IPPR, 2004. Opening It Up: Accountability and Partnerships. London: The Institute for Public Policy Research (IPPR).
- ITF, 2018. Private Investment in Transport Infrastructure: Dealing with Uncertainty in Contracts. Research Report. OECD/International Transport Forum. Available online at: https://www.itf-oecd.org/private-investment-transport-infrastructure-uncertainty
- Kotlikoff, L.J. & Raffelhuschen, B., 1999. Generational accounting around the globe. American Economic Review, 89(2), pp.161-166.
- Lindholm, R.W., 1970. The Value Added Tax: A Short Review of the Literature. Journal of Economic Literature, 8(4), pp.1178-1189.
- Medda, F.R., Carbonaro, G. & Davis, S.L., 2013. Public private partnerships in transportation: Some insights from the European experience. International Association of Traffic and Safety Sciences (IATSS) Research, 36(2), pp.83-87.
- Meunier, D., Quinet, A. & Quinet, E., 2013. Project appraisal and long term strategic vision. In 41st European Transport Conference. Frankfurt, 2013. Elsevier.
- Miranda, J., 2010. Do Public-Private Partnerships Create Value for Money for the Public Sector? The Portuguese Experience. OECD Journal on Budgeting, 1.
- NLC, 2017. The Future of Equity in Cities. National League of Cities; Center for City Solutions.
- Pagano, M.A. & Perry, D., 2008. Financing Infrastructure in the 21st Century. Public Works Management and Policy, 13(1), pp.22-38.
- Penyalver, D. & Turró, M., 2016. Intergenerational Redistributive Effects of Transport Infrastructure Financing. Case Studies from European and Non-European Countries. STAREBEI report for the European Investment Bank Institute. Available online at: http://institute.eib.org/map/map.html
- Penyalver, D. & Turró, M., 2017. Assessing the Fairness of a Project Financing Formula on Successive Generations. International Journal of Transport Economics, XLIV(1), pp.153-176 (https://doi.org/10.19272/201706701008).

- Penyalver, D., Turró, M. & Zavala-Rojas, D., 2017. Intergenerational Perception of the Utility of Major Transport Investments. Research in Transportation Economics. In Press (https://doi.org/10.1016/j.retrec.2017.11.001).
- Penyalver, D. & Turró, M., 2019. Redistribution Effects of Transport Infrastructure Investments. International Journal of Transport Economics (pending publication).
- Pilcher, J., 1994. Mannheim's sociology of generations: an undervalued legacy. British Journal of Sociology, 45(3).
- Pollock, A., Shaoul, J., Rowland, D. & Player, S., 2001. Public Services and the Private Sector. London: Catalyst.
- PPIAF, 2009. Toolkit for Public-Private Partnership in Road and Highways. World Bank Group. Available online at: https://ppiaf.org/sites/ppiaf.org/files/documents/toolkits/highwaystoolkit/6/pdf-version/2-35.pdf
- Regan, M., Smith, J., & Love, P.E. (2017). Financing of public private partnerships: Transactional evidence from Australian toll roads. Case studies on transport policy, 5(2), pp.267-278.
- Saavedra, P. & Bozeman, B., 2004. The "Gradient Effect" in Federal Laboratory-Industry Technology Transfer Partnerships. Policy Studies Journal, 32(2), pp.235-252.
- Sarmento, J.M., 2010. Do public-private partnerships create value for money for the public sector? The Portuguese experience. OECD Journal on Budgeting, 10(1), p.93.
- Sarmento, J.M., 2014. Public–private partnerships. Doctoral Thesis. Tilberg School of Economics and Management, University of Tilberg.
- Shaoul, J., 2003. A financial analysis of the National Air Traffic Services PPP', Public Money and Management. Public Money and Management, 23(3), pp.185-94.
- Shaoul, J., 2005. The private finance initiative or the public funding of private profit. In G. Hodge and C. Greve (eds.). In The Challenge of Public–Private Partnerships: Learning from International Experience. Cheltenham: Edward Elgar.
- Shaw, E., 2004. What matters is what works: the Third Way and the Private Finance Initiative. Hale, S.; Leggett, W. et (eds): The Third Way and Beyond. Manchester University Press.
- Soliño, A.S. & Gago de Santos, P., 2010. Transaction Costs in Transport Public–Private Partnerships: Comparing Procurement Procedures. Transport Reviews, 30(3), pp.389-406.
- Thomopoulos, N., Grant-Muller, S. & Tight, M.R., 2009. Incorporating equity considerations in transport infrastructure evaluation: Current practice and a proposed methodology. Evaluation and Program Planning, 32, pp.351-59.
- Turró, M., 2004. RAILPAG. Railway Project Appraisal Guidelines. European Commission and European Investment Bank (http://www.eib.org/projects/publications/railpag-railway-project-appraisal-guidelines.htm).
- Turró, M. & Penyalver, D., 2019. Hunting White Elephants on the Road. An Intergenerational Approach to Detect Wasteful Projects of Transport Infrastructure. Research in Transportation Economics (pending publication).
- Vecchi, V., Hellowell, M., della Croce, R. & Gatti, S., 2017. Government policies to enhance access to credit for infrastructure-based PPPs: an approach to classification and appraisal. Public Money & Management, 37(2), pp.133-140.
- Vickerman, R., 2004. Private Financing of Transport Infrastructure: Some UK Experience (http://www.pfingsttagung08.tuberlin.de/typo3/fileadmin/documents/infraday/2002/papers/vickerman-2002-private_financing_transport_infrastructure.pdf).
- Vining, A.R. & Boardman, A.E., 2008. Public-Private Partnerships. Eight Rules for Governments. Public Works Management and Policy, 13(2), pp.149-161.
- Vining, A., Boardman, A. & Poschmann, F., 2006. Public-Private Partnerships in the U.S. and Canada: There are no free lunches. Journal of Comparative Policy Analysis, 7, pp.1-22.
- Williamson, J.B. & Rhodes, A., 2011. A critical assessment of generational accounting and its contribution to the generational equity debate. International Journal of Ageing and Later Life, 6(1), pp.33-57.
- Williamson, O.E., 1976. Franchise bidding for natural monopolies-in general and with respect to CATV. The Bell Journal of Economics, pp.73-104.
- Wood, D.J. & Gray, B., 1991. Toward a Comprehensive Theory of Collaboration. Journal of Applied Behavioral Science, 27(2), pp.139-62.

- Ye, S., 2008. Patterns of Financing PPPs Projects. In Policy, Management and Finance for Public-Private Partnerships. In Akintoye and M. Becks (eds). London: Wiley-Blarckwell.
- Yescombe, E.R., 2007. Public–Private Partnerships: Principles of Policy and Finance. Burlington, MA: Butterworth-Heinemann.
- Zhang, X.Q., 2006. Public clients' best value perspectives of public private partnerships in infrastructure development. Journal of Construction Engineering and Management, 132(2), pp.107-114.

SECTION VII. CONCLUSIONS AND FUTURE RESEARCH

1. BACKGROUND

This thesis addresses the following particular issues:

(1). Firstly, it identifies and classifies "redistribution effects", which play an important role in investment decision-making, though rarely in an evident/transparent manner. Public investment projects analysts have tried to identify such effects both to create awareness of their weight in the decisions adopted by the different governments and to quantify and value redistribution in order to incorporate it in project appraisal in a rigorously way.

(2). Second, it deals with "intergenerational redistribution". This is actually a major subject of research that has been addressed notably in relation to externalities (e.g. climate change) and macroeconomic effects (i.e. of public debt). The thesis focuses, in particular, on the intergenerational effects stemming from the financial model adopted for major investments in transport infrastructure (public budget, loans, PPPs with user payment, etc.). This focus is relevant because the long-term effects of the financing formula finally adopted for infrastructure development projects have been disregarded until now in the decision-making process in spite of its potentially strong implications for the welfare of the successive generations affected by major projects.

(3). Finally, this thesis describes and develops the architecture of the *"Intergenerational Redistributive Effects Model"* (IREM), a microeconomic tool specifically developed to deal with the above-mentioned effects. This model provides a set of indicators to evaluate the financing formula adopted in major transport infrastructure projects in terms of fairness for future generations. The knowledge gained through the assessment of the intergenerational impact of different financing formulas under different (public) procurement scenarios has allowed developing an "intergenerational project rating scale", which is central to establish the convenience and fairness, in the long run, of the financing formula finally adopted for infrastructure delivery to establish its practicality and utility.

In sum, this thesis has allowed to place the redistributive effects of major transport infrastructure in a wider policy debate. Indeed, its main objective is to generate a broad discussion about the importance of enhancing the existing framework for project appraisal through the consideration of redistribution effects, with a particular focus on the analysis of intergenerational ones. The incorporation of such effects in project appraisal and, in particular, of the indicators of the intergenerational impact produced by the application of the IREM model complement and finally improve the conventional project assessment that is based on socioeconomic and financial analyses carried out with a simple "global" view of society and from the sole perspective of the current generation. The ideas developed in this thesis, which take a broader evaluation approach, should hopefully contribute to better decision-making processes for major investments in transport infrastructure.

2. IMPORTANCE OF THE ANALYSIS OF REDISTRIBUTION EFFECTS; AN OVERVIEW

There is a need for an appraisal framework ensuring that all relevant impacts are captured. The decision to build major projects of transport infrastructure is usually based on their ability to increase the resources available for the whole of society, which is usually evaluated through a conventional cost-benefit analysis (CBA). CBA focuses on the project's utility for users of the transportation system (efficiency benefits), despite the fact that such investments typically entail impacts of social, environmental and territorial nature over and above users-benefits. The differential (i.e. redistribution) effects of transport infrastructure development, which should be considered alongside the socioeconomic and financial assessments of a project, are seldom reflected in a systematic way in the decisions on major infrastructure investments.

The identification and classification of redistributive effects is actually a major contribution of this thesis. Efficiency benefits are unevenly distributed among the project's stakeholders and, in practice, transport infrastructure investment entails a diversity of redistributive effects that are relevant in the decision-making process. Most public policies defend indeed a bias in favour of a certain area, social group or specific agents. Even so, if the redistribution effects are strong, they may generate serious opposition by those sectors/groups negatively affected. How to incorporate redistributive effects in the decision-making process is actually an open question. In this sense, the typologies defined in **Section II** of this doctoral thesis are expected to cover most of the redistributive effects generated by transport investments that could be openly considered by decision-makers.

There is a need for putting in perspective the biases that redistributive effects introduce in favour or against an investment decision. Those of territorial, social and environmental nature have to be identified by means of a thorough analysis of redistribution effects. The comparison of the redistribution effects with the net economic value of the project, in money terms, produced by the CBA should provide the decision-maker with a solid indicator of its real interest. Besides, the *Stakeholders/Effects Matrix (S/E Matrix)* has proven over the years to be useful in providing insights on the political and social connotations that, in particular in the transport sector, are critical for the investment decision. The analysis of the redistributive effects among project's stakeholders is actually used to identify, among the various agents involved, who benefits from the project and who is negatively affected by it.

The intergenerational redistributive effects arising as a consequence of the misallocation between the project's socioeconomic net benefits and its financial provisions had not been identified until now. Traditional discounting brings the project outcomes that can be monetised, both socioeconomic effects and financial flows, to the extant generation's perspective. But transport infrastructure typically unfolds over decades and this implies that they potentially affect the well-being of individuals that are young today, even unborn, and thus cannot directly participate in the decision-making process and whose future costs and benefits are minored by the CBA discounting procedure. On the other hand, due to indivisibilities and economies of scale, transport infrastructure projects are often too large and too expensive, to be exclusively financed by the public budgets of the generation in which the decision is taken. It seems fair, in any case, to distribute the financial burden of the investment over the lifecycle of the project. The point is that this will have an impact on the successive generations, as the forthcoming users and/or taxpayers will end up enduring much of the actual payments in relation to the investment. Within this framework, it is logical to compare the gaps between benefits and costs generation by generation.

Section III presents the architecture of the *"Intergenerational Redistributive Effects Model"* (IREM), which is actually the most significant contribution of this doctoral thesis to academia. IREM has been developed from an overlapping generations approach to allow comparing the distribution of the expected socioeconomic net benefits with the flows of obligations (in terms of payments) that will be borne by the successive generations affected throughout the project's lifespan. The core idea underlying IREM is that well-conceived projects from a socioeconomic and financing point of view should be fair to future generations (i.e. the trend of the relation between net benefits and actual payments is positive towards the generations to come), and not entail significant differences among the various overlapping generations affected by the project. There are, of course, a number of issues arising from the application of this new and disruptive microeconomic tool that had to be resolved before applying the model to actual case studies. **Section IV** is actually devoted to the resolution of practical problems arising from the application of the model to real projects.

A major conclusion obtained from the knowledge gained from the practical application of IREM has been that it may be used to enhance decision-making processes in major infrastructure projects: **Section V** shows that the IREM indicators offer valuable insights to identify those projects that would represent a clearly unfair treatment of future generations (white elephants), in spite of showing an acceptable socioeconomic return for the current society. The procedure developed in this section encompasses both traditional economic approaches and the analysis of redistribution effects, with a special focus on the intergenerational ones. On the other hand, **Section VI** shows that besides the standard efficiency and financial considerations, an analysis of the intergenerational effects of the different procurement options and to compare these effects with those of the purely public financing alternative may provide added value to the traditional view on the *Value for Money* analysis of public-private partnerships (PPPs). In the practical exercise carried out in this section a main hypothesis is that private participation can deliver infrastructure and offer services at least equivalent in quality to those provided by the public sector through traditional infrastructure procurement, but with better outcomes in terms of both project costs, at least in terms of resources, and intergenerational effects.

3. GENERAL CONCLUSIONS

This epigraph summarises the most important conclusions derived from the different sections of this thesis. More detailed results and particular conclusions can be found in the last epigraph of each section. Thesis conclusions:

I. The efficiency of major transport projects in terms of resources should always be a critical factor in decision-making. However, efficiency benefits are unevenly distributed among the project's stakeholders and, in practice, transport infrastructure investment entails a diversity of redistributive effects that are actually relevant in the decision-making process. Thus, there is a need to look closely to redistribution issues (social, territorial, environmental, etc.) stemming from the project. If redistributive effects are strong, the sensitivity to unfair treatment of specific sectors/groups, which is increasing with the development of social networks, can be expected to lead to blockages of those investments that neither address public participation adequately nor incorporate measures to balance unfairness.

II. By their magnitude and their long lifecycle, major projects of transport infrastructure will affect many overlapping generations, so costs (in terms of actual payments) and benefits should be balanced to avoid distant generations to unfairly pay for investment adopted by the extant ones. The case of intergenerational redistributive effects diverges from the other redistributive effects because, by definition, future generations cannot participate in the decision. It is, however, their capacity to comply with future commitments what establishes whether or not an investment should be deemed to be efficient, financially sustainable and fair from an intergenerational perspective.

III. Traditional discounting models are inadequate to incorporate the perspective of the successive generations on investments unfolding over large time-spans because these conventional models pay insufficient attention to their actual welfare, which will be severely affected by the implications of the financial model adopted.

IV. There are two basic questions for the assessment of the fairness of a project financing formula on successive generations: on the one hand, to determine both what is the most appropriate method to group the affected individuals over the years in "generations" and, on the other hand, how the actual payments in relation with the main investment may affect the perceived utility of the project for the individuals concerned. In this thesis, an ad-hoc methodological approach, supported by a survey carried out specifically for this research, has been used to define the most suited timespan for a standard "annual generation", a critical element of the IREM and to establish the concomitant weighting curve that must reflect the sensitivity of society to the effects of major transport infrastructures.

V. IREM has been applied to a set of projects of different typologies under multiple financing and management options with the aim of gaining knowledge about the model's performance. The outcomes obtained stress that even efficient investments could entail severe redistributive effects among generations. It is in this sense that the financing formula is key for analysing intergenerational fairness measured in terms of payments and net benefits allocation over time. When the financial burden falls on future generations, as could be politically very convenient at the moment of making the decision to build, the financial structure adopted could entail that the project becomes a *white elephant* if, for instance, distant generations of users and/or taxpayers end up footing the bill stemming of the main investment while obtaining poor benefits from the project.

VI. The analysis of intergenerational impact that can be carried out with IREM has also proven to be useful to complement the traditional view on the *Value for Money (VfM)* of private participation in project financing and management, through some type of public-private partnership. Current methods of project appraisal, in particular cost-benefit analysis, look at actions from the point of view of today's society. Besides, decision makers usually determine the financing formula after the decision to build has been adopted. This could severely affect some of the objectives that were included in the initial considerations for the project construction. In this sense, the knowledge gained from the application of the IREM model to a number of case studies shows that the analysis of the project's intergenerational impact may provide valuable insights on the long-term added value that could be obtained potentially from private participation in project financing and management with regards to publicly managed infrastructure-solutions.

To sum-up, when redistribution issues are not properly taken into account and correctly managed, a project easily ends up with blockages that unavoidably affect its efficiency. In this sense, pursuing fairer investments from an intergenerational perspective may help public managers to both prove that the investment strategy, i.e. the combination of project's effects and its financial package, is useful to sustain the well-being of future generations, and adopt financing formulae that represent suitable redistributive effects among the successive generations involved in long-term investments.

4. FUTURE RESEARCH

This doctoral thesis is expected to cover most of the redistribution effects stemming from major projects of transport infrastructure. It has focused in their identification and classification and developed the concept and quantification of intergenerational effects. However, a better understanding of the actual redistribution effects of transport infrastructure remains a major challenge for those trying to foresee the economic and social development impacts of such investments. On the other hand, the consideration of redistribution effects alongside efficiency in decision-making can be challenging in practice. The creation of a solid evaluation methodology and a procedure to adequately present them in the citizen participation process and finally to the responsible of the decision still requires additional research. This could eventually lead to a formalised and systematic way to complement the traditional CBA with the incorporation of proper indicators of the accomplishment of the political goals behind redistribution.

It is also necessary to be aware that certain effects of transport infrastructure projects (e.g., development of urban conurbations around metropolises) might trigger redistribution impacts of second order. While most of these secondary effects have already been identified in the first count, their actual consequences on the territory and on different social groups would require additional research, in particular about their interactions, in order to prevent double counting. For instance, the environmental externalities resulting from the expected activity generated by the project may bring redistribution issues in the long run, as they will affect differently many generations. Also, some territorial and social impacts (e.g., segregation phenomena between income groups) may happen beyond the target area envisaged for the project. Incorporate this type of issues in the decision-making process is not easy. Within the redistribution framework, it seems necessary to carry out studies seeking to define clear indicators, notably on the expected effects of transport infrastructure on long-term economic and social development. Reducing the subjectivity of politically-oriented redistribution should improve the quality and fairness of the decisional process.

The *Stakeholders/Effects Matrix*[1] represented a significant methodological advance in the identification of the transfers amongst the various agents participating in a major project. In projects of certain complexity in which the distribution of the costs and benefits among the agents involved is critical, the redistributive effects among project-linked stakeholders may have strong political and social connotations. In this sense there is a need of studies to bring light on the distribution of financial and economic flows among stakeholders. They are particularly required to analyse the fairness of projects in which the private sector or other hybrid[2]

[1] *Turró, M., 2004. RAILPAG. Railway Project Appraisal Guidelines. ed. European Commission and European Investment Bank* (http://www.eib.org/projects/publications/ railpag-railway-project-appraisal-guidelines.htm).

[2] Organisations with ownerships rights distributed between a government and either other governments or, more commonly, private actors. More details in: *Vining, A.R. & Weimer, D.L., (2016). The challenges of fractionalised property rights in public-private hybrid organisations: The god, the bad, and the ugly. Regulation & Governance, 10(2), pp.161-178.*

organisations are assigned major responsibilities in project financing and management, as existing experience is inconclusive.

The main contribution of the thesis is related to intergenerational effects. Major infrastructure projects can generate strong differential effects among overlapping generations during the project lifecycle. Indeed, this research has shown that, in particular, projects showing a combination of modest usefulness from a socioeconomic point of view –in terms of CBA outputs– and inappropriate financing formulae may result in redistribution effects that are very unfair, even regressive, for generations to come. Might unfair treatment of future generations be a generalised phenomenon? Why the analysis of the intergenerational fairness related to the financing formula of the project should be relevant for decision makers? To respond to both questions, further research is necessary. The issue of intergenerational redistribution at microeconomic level has seldom been theoretically addressed and never targeted until now, in part because there was not a solid approach to do it. On the other hand, academics and researchers have traditionally focused their effort on the analysis of the macroeconomic redistribution issues stemming from a particular fiscal policy or pension system rather than in the redistribution issues of a particular investment portfolio or project, perhaps because there is a generalised conviction that today's investments will benefit future generations forever. But the point of concern is that, while the government promoting the investment may set up transfers to quickly correct unfair treatment between, for instance, social groups, future generations cannot ask previous generations to pay more for the project. They will inherit, therefore, a financial burden that either they will support themselves, as originally expected, and probably postpone, as a consequence, other investments that might be potentially important for them, or to pass the burden to future generations through refinancing. In any case, both alternatives mean an opportunity cost that should be put into perspective.

A question that also deserves some research is to what extent some of the budgetary constraints that society face today are due to investments that have been used for the exclusive benefit of past generations or if they are mostly fair for the generations that were unable to participate in the global decision-making set up. An ex-post analysis of a representative sample of major projects developed in former decades by EU member countries could provide an answer to this question. As this exercise is politically sensitive, in particular under the present situation of public debt control, it would be probably easier to concentrate on projects supported either with EU funds (grants) or with soft loans from the European Investment Bank to check if they should be labelled as fair or as unfair/regressive for the intergenerational perspective. The application of IREM within the ex-post evaluations that, in the past few years, have been carried out by European Commission would already provide an interesting view of the issue.

The political interest of this exercise should not be disregarded. If the results of the ex-post evaluation indicates that most EU-supported investments would be deemed productive, financially sustainable and intergenerationally fair because they have been effectively delivering over the years economic, social and environmental benefits higher than its costs and their financial burden is well distributed, European policy-makers should be bound to reconsider the rationale of the EU rules for deficit/debt public accounting –European Systems of Accounts (ESA, 2010). For well-planned and identified investment priorities that may be central for economic growth and sustainable development requiring massive long-term financing, independently if they are conveyed through public agencies, hybrid vehicles or private investors, an exclusion from the deficit/debt figures should be considered when they are properly appraised[3]. In a first step, EU-supported projects, which require a CBA analysis that could easily incorporate an intergenerational assessment, could benefit from this waver from ESA. On the

[3] The *white elephants* paper (Turró & Penyalver, 2019) provides some guidelines in this regard.

other hand, the fact that projects get substantial grants from the EU budget and thus from the EU taxpayer, introduces an intergenerational impact that deserves a specific analysis of its effects on the IREM indicators.

It must be recognised that the IREM model offers a solid basis for the analysis of project fairness across the generations affected, but its practical application is relatively complex. The availability of adequate information, in some cases due to confidentiality issues is a major handicap. Besides, in order to determine to what extent intergenerational unfairness may be avoided/limited through improved financial packages or having recourse to alternative financing mechanisms, there is a need for additional research with larger samples of case studies. A model requires systematic application and progressive adaptation to become a reference for practitioners. For IREM to play a central role in project appraisal, additional research is needed, especially to enhance the precision of its outputs. The following lines of research appear as the most relevant for this purpose:

- Assets and maintenance and replacement costs. The impact in the model of the years when heavy maintenance costs should take place or when the replacement of assets representing substantial expenditure, such as rolling stock, is programmed deserves some analysis. The research should consider how these investments are financed in practice. The impact on the IREM outputs of detaching them, and even routine maintenance, from the optimal moment and their double effects in terms of both negative socioeconomic effects and financing flows should be analysed. The corresponding evolution of asset valuation over the lifecycle of the infrastructure and the use in the model of depreciation and residual values also deserves further research.

- Extrapolation of the project performance. The generational analysis ends up a number of years after the period of analysis adopted in CBA, 10 years according to the "future branch" of the weighting curve that defines the standard-annual generation for the IREM model. In this additional period, the time-profile of the net socioeconomic benefits is extrapolated according to the trend shown after the ramp-up period. However, major projects of transport infrastructure, especially those of urban nature (tramway, metro, etc.), may be under-dimensioned at the end of their economic lifecycle, with a clear (negative) impact on the estimates of socioeconomic benefits in the last years of the project cycle. They are not affecting very much the results of the CBA due to discounting, but they may have substantial intergenerational effects. Future research should deepen in what is the most adequate extrapolation approach to the actual performance of the different types of transport infrastructure projects.

- Annual generation concept. There is space for more research on the definition of the weighting curve linked to the concept of annual generation. Both different types of transport infrastructure projects and different contexts of the project implementation could require ad hoc weighting curves. Future research should focus on to what extent the IREM outputs may vary according to deviations in the estimates of the weights linked to the concept of annual generation.

- Sensitivity analysis for the IREM outputs. As a result of the different scenarios that can be envisaged for a project performance in the short (construction phase) and the long run (project performance), there is a need to define a proper procedure for sensitivity analysis. This analysis should focus, on the one hand, on the implications of the envisaged deviations in terms of cost overruns, delays in project commissioning and revenues estimates for the financial needs, which necessarily affect the financial package linked to project development. Besides, the sensitivity analysis should take into consideration possible deviations of the expected socioeconomic benefits as a direct consequence of an enlarged construction phase as well as on project underperformance.

- The intergenerational impact of project-related taxes: the government promoting the investment pays and receives taxes, mainly VAT, during the project construction and after its implementation. Other taxes may be also levied on additional fuel consumption of induced traffic, which should be reduced from the taxpayers' contribution. Taxes on stakeholders who are not final users (i.e. corporate taxes) or on certain components of the project (i.e. local taxes) have their own timing and affect the financing of the project. The moment in which the payment of taxes occurs has, in principle, a minor impact on IREM indicators, but it is still necessary to pay attention to this issue, in particular when projects are structured as PPPs because it is implicit in the project finance mechanism the financing of certain taxes, such as VAT, through short- or mid-term (miniperm) loans.

- Fiscal policy. Public subsidies, either in form of direct financial support to users of the transport sector or in form of indirect support to companies or their shareholders through fiscal deductions have clear effects in the design of the financial package for infrastructure development. If subsidies are strong, the private sector is traditionally more willing to provide financing through PPPs, which has in turns an impact on the overall expenditure linked to the project. Besides, in the case of PPPs, taxes on the concessionaire are typically charged on operators, on transportation users and/or taxpayers. In other words, the financing mechanism is linked, to certain extent, to the overarching fiscal scheme. It is in this sense that there is a need of additional research to establish how fiscal policy may have an influence in the positive intergenerational pattern found for PPPs.

- Inflation. Financial cash flows are typically incorporating inflation forecasts, particularly relevant when loans are subject to fixed interest. In the IREM model the comparison between socioeconomic net benefits and the financial burden on specific years must be consistent and it is, therefore, carried in constant terms. Inflation estimates may thus be important in the results of the model. The influence of inflation discounting on the assessment of intergenerational effects should be analysed in depth.

- Finally, as there could be multiple institutions applying IREM from CBAs of different quality (and bias), it is necessary to raise the question of what standards have to be used for CBA (e.g., unlike UK Treasury, the EC guide states that the economic impact of project' spillovers will not be taken into account in the efficiency analysis) and whether there exist common patterns to value time savings, GHG emission reduction, etc. In this case, shadow prices could entail significant differences for CBA's outcomes.

This doctoral thesis opens up a number of exciting research lines for future practitioners. The most challenging ones are those related to the potential of IREM to enhance the decision-making process of major public investments. There are, however, many areas of knowledge, from the detailed level of definition of the model to its potential use in the more abstract, but socially and politically relevant, fields of ethics and democratic representation that are also in quest of more extensive research.

APENDIX. REPORTS OF INTERNATIONAL REVIEWERS ON THE QUALITY AND ORIGINALITY OF THIS DOCTORAL THESIS

REPORT FROM THE EXTERNAL REVIEWER 1

Model IE
1/2

INFORME EXPERT EXTERN
INFORME EXPERTO EXTERNO
EXTERNAL REFEREE REPORT

Nom de l'expert/ Nombre del experto/ Name of the referee: **Massimo Florio**
Categoria/Categoría/Category **Professor of public economics**
Departament, Universitat a què pertany/Departamento, Universidad a la que pertenece/ Department, University to which s/he belongs **Department of Economics, Management, Quantitative Studies, Università degli Studi di Milano, Italy**

Nom del doctorand que presenta la tesi/ Nombre del doctorando que presenta la tesis/ Name of the student presenting the thesis: **Domingo Peñalver Rojo**

Especifiqueu les raons que avalen la qualitat de la tesi per a la seva defensa pública : Especificar los motivos que avalan la calidad de la tesis mencionada para su defensa pública: Specify reasons endorsing the quality of the above-mentioned thesis for its public reading:

Quins objectius s'han assolit amb la tesi ?
¿Qué objetivos se han logrado con la tesis presentada?
What objectives have been achieved with the thesis?

The objective of the thesis is a study the intergenerational impact of a major transport infrastructure according to its funding mechanism. This is considered by the candidate a relevant topic in transport economics because - while one of the usual discounting approach can take care of 'aggregate' intertemporal considerations - such approaches would not consider if one or more specific 'generations' suffers a negative gap between benefits and costs. An accounting model is proposed to deal with this and other related analytical issues. This is seen by the author as linked to a distributional impact of the project, not to be confused with other distributional impact such as among groups of individuals by income,. location, gender, intra-generation age, and so on. In this context, the thesis applies a model to predict effects of projects across generation, and to identify 'white elephants', i.e. particularly bad projects. It also analyses the implication of certain funding mechanisms. The thesis also wants to measure if empirical (survey) data for intertemporal values fit a specific distribution.

Originalitat del treball :
Originalidad del trabajo:
Originality of the work:

I think this is an under-researched topic, because most of the theoretical literature is framed in terms of a representative 'eternal' agent (or a dynasty of agents). In fact in such literature, as the candidate rightly claims, it is not necessary to specify the duration of life cycles of each generation. In this perspective the thesis is a contribution to CBA, as it introduces a focus on distributional impact across generations who may suffer the burden and enjoy the benefits of the project in a disproportionate way. The thesis draws from papers published in international refereed filed journals, which have already evaluated part of the work in terms of originality.

Metodologia emprada / hipòtesis contrastades :
Metodología usada / hipótesis contrastadas:
Methodology used / hypotheses tested:

There are a variety of methods in the thesis. After a literature review in most chapters, the treatment of the topic is through comprehensive logical frameworks and matrixes; some mathematical equations; and some statistical elaboration of empirical data.

Modell IE
2/2

Valoració absoluta i/o ponderada de la tesi en relació amb altres treballs d'investigació:
Valoración absoluta y/o ponderada de la tesis presentada en comparación con otros trabajos de investigación:
Absolute and/or relative assessment of the thesis in comparison with other works of research:

My assessment ot the thesis is positive as it contributes to an important area of research, CBA of transport projects, in a new perspective. Given the originality and the careful discussion, my absolute evaluation is of a very good work.

Considera que la tesi esmentada és apta per al tràmit de lectura i la defensa pública?
Considera que la tesis anteriormente mencionada es apta para su lectura y defensa pública? In consideration of all the above, is the thesis judged to be suitable for public reading?

Sí/yes [X] **No** [ ]

Observacions:
Observaciones:
Observations:

Signatura i data
Firma y fecha
Signature and date

2019/02/02

Milano

(*) Si és necessari adjunteu les respostes en els fulls annexos/ Si es necesario adjunten las respuestas en las hojas anexas/ If necessary, enclose the answers in the annexed sheets.

REPORT FROM THE EXTERNAL REVIEWER 2

Model IE
1/2

INFORME EXPERT EXTERN
INFORME EXPERTO EXTERNO
EXTERNAL REFEREE REPORT

Nom de l'expert/ Nombre del experto/ Name of the referee: Georgina Santos
Categoria/Categoría/Category: Senior Lecturer (Profesora Asociada)
Departament, Universitat a què pertany/Departamento, Universidad a la que pertenece/ Department, University to which s/he belongs: School of Geography and Planning, Cardiff University, Cardiff, UK

Títol de la tesi/ Título de la tesis/ Title of the thesis: Intergenerational redistributive effects due to the financing formula of investments in transport infrastructure – A microeconomic analysis of the intergenerational impacts of major programmes and transport infrastructure projects

Especifiqueu les raons que avalen la qualitat de la tesi per a la seva defensa pública:
Especificar los motivos que avalan la calidad de la tesis mencionada para su defensa pública:
Specify reasons endorsing the quality of the above-mentioned thesis for its public reading:
Quins objectius s'han assolit amb la tesi?
¿Qué objetivos se han logrado con la tesis presentada?
What objectives have been achieved with the thesis?

The objectives of this thesis were:

a) To understand and analyse any redistributive effects of finance mechanisms to fund major transport infrastructure projects, and
b) To propose ways of introducing these redistributive effects in the decision-making process

Both objectives were achieved, and are very likely to have an impact on policy making in Spain, and potentially, in the rest of Europe and throughout the world.

Nom del doctorand que presenta la tesi/ Nombre del doctorando que presenta la tesis/ Name of the student presenting the thesis: Domingo Peñalver Rojo

Model IE
2/2

Originalitat del treball:
Originalidad del trabajo:
Originality of the work:

The work presented in this thesis is original because it develops a novel "Intergenerational Redistributive Effects Model" (IREM), which allows the decision/policy maker to analyse the intergenerational impacts of major transport infrastructure projects. Although many countries, such as for example the UK, do take redistributive impacts of major transport projects into account, they neither consider different generations, nor do they have a model to undertake such analysis. IREM, therefore, is a powerful tool, which yields utility indicators, which in turn can be used for decisions regarding financing of projects and private stakeholders' participation. Furthermore, IREM can potentially be used to evaluate a number of (or even all the) investment projects or policies undertaken by a jurisdiction, region or country, provided there is a common starting date and a reasonably comparable CBA.

Metodologia emprada / hipòtesis contrastades:
Metodología usada / hipótesis contrastadas:
Methodology used / hypotheses tested:

The author of this thesis uses the following methods:

Literature reviews -the first chapter is entirely a literature review but the other chapters also contain literature reviews. These are critical, insightful and comprehensive and help put the different problems in context.

Cost-Benefit Analysis – starting with the simple well-tested CBA technique, the candidate extends the basic the concept/model to make a difference between financial impact (cash flows) and socio-economic costs and benefits (for which there are no market prices and which need to be monetised). This is especially important because in many cases part if not all of the financial costs of infrastructure projects are financed through bonds. He then moves on to define annual generations, GAP for each annual generation, time profile of generational GAPS and on the basis of these, a generational unfairness indicator. This is a crucial contribution, with an important application: to measure distributional impacts across generations.

Survey – a survey was carefully designed and administered in order to identify the perception of Catalonians on the effects that investments in transport infrastructure can have on the welfare of their generation and on future ones. This was then fed into the work carried out toi define annual generation and associated concepts.

Model IE
3'2

Practical application – a sample of 3 High Speed Rail Projects, 9 Urban Public Transport Projects, 8 Motorway projects and 2 Joint Projects were used as examples where IREM was used. The results are discussed in detail and although interesting, the most important contribution of this section is that it shows that IREM can be used in practice, and it is not a mere theoretical construct.

Embedded in the methodology used in this thesis there are also a number of well established, sometimes fairly sophisticated, statistical techniques, which are used at various points and without which intermediate and final numerical results would have not been possible.

Valoració absoluta i/o ponderada de la tesi en relació amb altres treballs d'investigació:
Valoración absoluta y/o ponderada de la tesis presentada en comparación con otros trabajos de investigación:
Absolute and/or relative assessment of the thesis in comparison with other works of research:

The findings of this doctoral thesis have been published in four academic journals of high international standing, indexed in Thomson Reuters, and there is a fifth publication currently undergoing a second round of peer-review. This is well above the standard generally seen in doctoral theses submitted within the field of transport studies in the UK, even those submitted as a compendium of publications.

The results are of great relevance for policy making and constitute an important contribution to academic knowledge.

With the above in mind my assessment of this thesis is 'OUTSTANDING'.

Considera que la tesi esmentada és apta per al tràmit de lectura i la defensa pública?
Considera que la tesis anteriormente mencionada es apta para su lectura y defensa pública?
In consideration of all the above, is the thesis judged to be suitable for public reading?

YES

Observacions/ Observaciones:/ Observations:

The thesis constitutes an original contribution to knowledge, and therefore worthy of public reading.

Model IE
4/2

Signatura i data
Firma y fecha
Signature and date

School of Geography and Planning
Cardiff University
Glamorgan Building
King Edward VII Avenue
Cardiff CF10 3WA

Georgina Santos
5 March 2019