Available online at www.sciencedirect.com

ScienceDirect

Procedia - Social and Behavioral Sciences 111 (2014) 400 – 409

Procedia
Social and Behavioral Sciences

EWGT2013 – 16th Meeting of the EURO Working Group on Transportation

Transport infrastructure project evaluation using cost-benefit analysis

Heather Jones[a,*], Filipe Moura[a], Tiago Domingos[b]

[a] CESUR, Center for Urban and Regional Systems, Department of Civil Engineering and Architecture, Instituto Superior Técnico, University of Lisbon, Av. Rovisco Pais n°1, 1049–001 Lisbon, Portugal
[b]IN+, Center for Innovation, Technology and Policy Research, Energy and Environment Scientific Area, Department of Mechanical Engineering, Instituto Superior Técnico, University of Lisbon, Av. Rovisco Pais n°1, 1049–001 Lisbon, Portugal

---

Abstract

The advent of megaprojects is exacerbating the need for a comprehensive tool for decision making. Financial resources are scarce and cost-benefit analysis (CBA) can help decision makers select the most efficient allocation of these resources. This paper addresses CBA as an evaluation tool and its major weaknesses. We conclude that the treatment of residual value (RV) is inadequate and needs further research. RV represents the value of the infrastructure at the end of its project lifetime and the value that the asset generates over time. The current methods for calculating RV do not properly reflect the true value.

Keywords: Cost benefit analysis; transport infrastructure; decision making; residual value.

---

1. Introduction

The growing world population and its inherent need for increased transportation is straining existing transportation infrastructure and creating the need for megaprojects. Financial resources are scarce and therefore must be allocated efficiently. Properly valuing transportation infrastructure in cost-benefit analysis (CBA) will allow for the most efficient allocation of resources and allow us to do more with less resources.

The perpetuation of megaprojects and their habitual cost and schedule overruns (Flyvbjerg, Bruzelius, & Rothengatter, 2003) coupled with the magnitude of the investment creates a need to carefully assess the costs and benefits of infrastructure projects (Nash, 1991). Many governments and funding agencies require a CBA (EC, 2008; OECD, 1969; UN, 1972; World Bank, 1975; and Mishan and Quah, 2007) to aid in allocating scarce

---

* Corresponding author. Tel.: +351-218-418-412; fax: +351-218-409-884.
E-mail address: heatherj@mit.edu

doi:10.1016/j.sbspro.2014.01.073

resources efficiently. For European Union (EU) member states, CBA is required for funding from the Instrument for Pre-Accession countries, Cohesion Fund or Structural Funds. However, there has not been much improvement in the way that these projects have been evaluated and the issue of residual value (RV) has been largely ignored.

Clearly an improvement to the way infrastructure investments are evaluated is needed. CBA has been used extensively for evaluating infrastructure investments but it has a few drawbacks. This paper makes a comprehensive review of critiques of CBA. Infrastructure residual value, together with considerations of project lifetime and discounting rates, has been over looked by CBA practice, which we also address with more detail here. In section 2, we begin with a brief review of the CBA concept followed, in section 3, by a review of the main weaknesses of CBA acknowledged in the literature. Section 4 overviews the current practice in evaluating residual value and identifies its main problems, Finally, section 5 addresses the issues of project lifetime and discounting rates. We conclude with some final remarks in section 6.

2. Cost-benefit analysis

CBA is a formal process for evaluating a project that evolved from the economic constructs of consumer surplus and externality. It then moved into a formal regulated process based upon work by economists and government agencies and is now required by many entities for project approval, seeking the efficient allocation of resources (World Bank, 2004; Ninan, 2008). CBA has been called the “single most important problem-solving tool in policy work” (Munger, 2000). It is a decision making tool that is one of the most widely accepted and applied methods for project appraisal for large-scale infrastructure investments in the public sector (Nickel, Ross & Rhodes, 2009) because it provides many benefits including, a model of rationality, creating, evaluating and comparing alternatives including different scales for the alternatives, monetizing the costs and benefits and guiding decision makers.

CBA weighs the pros and cons of a project or policy in a rational and systematic process. CBA inherently requires the creation and evaluation of at least two options, “do it or not” plus it requires an evaluation at several different scales (nothing, minimum and all as the least requirements) (OECD, 2006; EC, 2008; Ninan, 2008). Decision makers must assess who are the gainers and losers across both space and time (Ninan, 2008). It ensures that the net aggregate benefits to society outweigh the net aggregate costs (Nickel, Ross & Rhodes, 2009). Therefore, it monetizes both inputs and outputs. This monetization is founded on a socially accepted valuation system that transforms the inputs into a monetary value using actual or shadow prices (Vining and Boardman, 2005) that expresses social welfare that should then be maximized (Guhnemann, 1999). It explicitly states economic assumptions so they are not overlooked or remain implicit (World Bank, 2004), including externalities, thus integrating economic and environmental considerations into decision making (Beder, 2000). It also includes accounting for time through the use of a discount rate (Ninan, 2008; Munger, 2000). Essentially, it seeks to enumerate all direct costs and benefits to society of a particular project, assign monetary values, discount them to a net present value and add them into a single number to evaluate the project (Nickel, Ross & Rhodes, 2009).

3. Weaknesses of cost-benefit analysis

CBA has been criticized on many fronts such as its decision making process (Mouter, Annema, & van Wee, 2011), its process (Beukers, Bertolini, & Brommelstroet, 2012), it monetizes non-market goods (Mackie & Preston, 1998; Niemeyer & Spash, 2011), it does not account for equity Banister & Berechman, 2000), the openness of the interpretation of its results (World Bank, 2004), its scrutiny by the public (Persky, 2001), its need for completeness and correctness (Annema Koopmans, & van Wee, 2007), its lack of being understood (Heinzerling & Ackerman, 2002), its ethics (van Wee, 2012) and its discounting of long-term environmental consequences (Ludwig, Brock, & Carpenter, 2005).

In the end, the analysis is only as good as the assumptions or estimates. "The right decision only results if prices used by decision makers correctly reflect the social values of inputs and outputs at the social optimum or "shadow prices"; market prices seldom do this so it is important to "arrive at adequate and consistent valuations where market prices fail in some way" (Layard & Glaister, 2003). The CBA is extremely sensitive to the values used for the different assumptions. A major error in any of these can cause a bias in the results or even change the outcome from negative to positive or vice versa. For example, an extreme error in one of the assumptions for the demand estimation can cause the benefits to exceed the costs for a new road. It has been repeatedly pointed out that placing a value on non-priced impacts is difficult and can probably not result in an accurate price (Annema Koopmans, & van Wee, 2007; Heinzerling & Ackerman, 2002; Niemeyer & Spash, 2001). For the purpose of this study we will focus on the inputs and their calculations used in performing a CBA for a specified alternative. Table 1 is a list of critical factors that are made in a CBA and common flaws with each.

Table 1. Major Weaknesses of Cost-Benefit Analysis

Factor	Weakness	Sources
Traffic Forecast	Commonly off by 20%-60% (usually overestimated)	Skamris & Flyvbjerg, 1997; Flyvbjerg, Bruzelius, & Rothengatter, 2003; Flyvbjerg, 2005; World Bank, 2005a; Mayer & McGoey-Smith, 2006; van Wee, 2007; Salling & Banister, 2009; Rasouli & Timmermans, 2012
Cost Estimation	Overruns of 50%-100% are not uncommon (usually underestimated)	Skamris & Flyvbjerg, 1997; Flyvbjerg, Bruzelius, & Rothengatter, 2003, Flyvbjerg, Skamris Holm, & Buhl, 2004; Flyvbjerg, 2005; Mayer & McGoey-Smith, 2006; van Wee, 2007; Salling & Banister, 2009; Rasouli & Timmermans, 2012
Discount Rate	Impossible to forecast long-term. Higher rates favor smaller investment or short term benefits	Farber & Hemmersbaugh, 1993; Weitzman, 1994; Weitzman, 1998; Weitzman, 2001; Florio & Vignetti, 2003; RAILPAG, 2005; Florio, 2006a; Florio, 2006b; EC, 2006
Value of Life	Hard to determine, no agreement on method or value	Farber & Hemmersbaugh, 1993; Hanley & Spash, 1993; Gerrod & Willis, 1999; Miller, 2000; Dubgaard, Kallesoe, Petersen, and Ladenburg, 2002; Mrozek & Taylor, 2002; Quinet & Vickerman, 2004; de Blaeij, Florax, Rietveld, & Verhoef, 2007; Bellavance, Dionne, & Lebeau, 2007; Trottenberg & Rivkin, 2011
Safety	Wide agreement on method and value. Developing countries have some difficulty	Bristow & Nellthorp, 2000; Grant-Muller, Mackie, Nellthorp, & Pearman, 2001; World Bank, 2005b
Value of Time	Complex procedure, no consensus on which variables are relevant and relationships among values	Hanley & Spash, 1993; Rainey, 1997; Gwilliam, 1997; Mackie & Preston, 1998; Gerrod & Willis, 1999; Banister & Berechman, 2000; Dubgaard, Kallesoe, Petersen, and Ladenburg, 2002; Mackie, Wadman, Fowkes, Whelan, Nellthorp & Bates, 2003; World Bank, 2005c; van Wee, 2007; Trottenberg and Rivkin,. 2011
Regional Impacts	Does not account for network or crowding out effects	Rietveld, 1989; EC, 1997; Banister & Berechman, 2000; Sieber, 2001; Vickerman, 2007; Flyvbjerg, Bruzelius, & Rothengatter, 2003, Mairate & Angelini, 2006; Banister, 2007; Coto-Millan, Inglada, & Rey, 2007; van Wee, 2007; ITF, 2011
Local Impacts	Does not account for agglomeration and land use interaction	Chintz, 1961; van Wee, 2007; Banister, 2007; Martinez, 2010
Equity	Not included in CBA. Monetization not universally accepted.	Mera, 1967; Hewings, 1978; Richardson, 1979; Bateman, Turner, & Bateman, 1993; Masser, Sviden, & Wegener, 1993; de Silva & Tatam, 1996; Banister & Berechman, 2000; Beder, 2000; Bristow & Nellthorp, 2000; Feitelson, 2002; Persky, 2001; Heinzerling & Ackerman, 2002; Annema Koopmans, & van Wee, 2007; Ninan, 2008; Thomopoulos, Grant-Muller, & Tight, 2009; Shi & Wu 2010, Martens, 2011
Environmental Impacts	Difficult to monetize with large uncertainty ranges. LCA is not performed, thus not accounting for	Culhane, 1987; Buckley, 1991; Button, 1994; EC, 1995; Wood, Dipper, & Jones, 2000; Banister & Berechman 2000; Niemeyer & Spash, 2001; Heinzerling & Ackerman, 2002; Gijsen & van der Brink, 2002; Flyvbjerg, Bruzelius, &

	impacts from construction and maintenance of infrastructure	Rothengatter, 2003, van Wee, van der Brink, & Nijland, 2003; Laird, Nellthorp, & Mackie, 2005; Chester & Horvath, 2007; van Wee, 2007
Residual Value	Often overlooked. No agreement on methodology.	Lee Jr., 2002; Florio & Vignetti, 2003; RAILPAG, 2005; EC, 2006; IASB, 2006; Edgerton, 2009; Matria, 2012

Some inroads have been made into the major weaknesses of CBA but work remains in varying degrees. Further refinements are needed for some weaknesses such as traffic forecasts, cost estimates, discount rate, VSL and VOT. While others need considerable advances such as the inclusion of land use-transportation interaction and regional impacts and network effects. A few need groundbreaking improvements such as lifecycle energy and environmental impacts inclusion and monetization, equity inclusion and monetization and new RV estimation to reflect the value the asset generates over time. This paper addresses the need for improvements in RV calculation.

4. Residual Value and calculation methods

Residual value (RV) is an important component of CBA and it represents the infrastructure value at the end of its projected lifetime. It can also be interpreted as the value generated by the asset over time. Properly accounting for this will show the true value of the asset. Often times, RV is overlooked during CBA, which artificially depresses the projects returns (Florio & Vignetti, 2003). As such, current methods for calculating RV do not properly reflect the value that the asset generates.

The RV of the project investment is accounted as a revenue item in the final year of the CBA. It reflects the remaining value of the investment (standing debt and standing assets such as buildings or machines). It can be calculated as the residual market value of fixed capital as if they were sold at the end of the time horizon or more simply as the residual value of all assets and liabilities. The discounted value of every net future receipt after the time horizon should be included, making it the same as the liquidation value (EC, 2008).

In theory, the RV should be calculated as all of the future forecasted flows from the beginning of the project to infinity, discounted to present value (PV). However, it is often calculated differently in practice, most commonly as the average physical lifetime value of stock of fixed capital such as buildings, machinery and equipment (Florio & Vignetti, 2003). It is also calculated as the PV of expected net cash flows during the years of economic life outside the reference period if the economic life exceeds the project lifetime period (EC, 2006). Another method calculates it as the estimated amount that an entity would currently obtain from disposal of the asset, after deducting the estimated costs of disposal, if the asset were already of the age and in the condition expected at the end of its useful life (IASB, 2006; Edgerton, 2009). RV is also defined more simply as future benefits (beyond the current lifetime) minus recurring costs (Lee Jr., 2002).

RV is often ignored in transportation CBAs. Table 2 presents some references on how RV is approached for transportation infrastructures. Port project analyses have not generally included a residual value. It is suggested that RV should be included in port project analysis and particularly when a public-private partnership (PPP) is involved (Theodoropoulos & Tassopoulos 2011). RV is of particular importance in concessionaire situations. RV can indirectly stipulate the quality of service and the state and functionality of the infrastructure at the end of the concession period.

Table 2. Residual Value in Transportation Infrastructure Literature

Source	Position
Lee Jr.(2002)	Some investments continue infinitely and should have a RV calculated for them
EC (2008)	Economic life of the project and RV for any useful assets after time horizon
Odgaard, Kelly, and Laird (2006)	RV is composed of the lifetime of the infrastructure and the depreciation profile. The treatment varies by country
Campos, de Rus, and Barron (2007)	RV is difficult to calculate because rail has different assets with different useful lives and

	depreciation rates
Annema Koopmans, and van Wee (2007)	Actual RV calculations by Dutch CBA for infrastructure projects from 2000-2006
EC and EIB (RAILPAG, 2005)	RV should be calculated individually for the different components
ACT (2008)	RV should be calculated using different lifetimes for the following key components: fixed infrastructure (tracks and tunnels), earthworks and drainage, stations and rail cars
RITES and Silt (2010)	RV is calculated for each infrastructure item
Theodoropoulos and Tassopoulos (2011)	RV should be included in analyzing port projects

When included in CBA, RV is often calculated using different methods. One approach is that since there are different assets (e.g., tracks, buildings, etc.), it is difficult to arrive at an accurate value for RV for the overall infrastructure. In order to simplify calculations, straight-line depreciation can be used and it can be adjusted for the year of acquisition for assets such as rolling stock (Campos, de Rus, & Barron, 2007). This depreciation method is the most commonly used method for calculating RV. This basically means that the RV is equal to the non-depreciated amount of the asset. It can be calculated for any given year. The project lifetime period should be shorter than the depreciation period for the asset. It is not the best nor the most comprehensive method. Its benefits are that it can be calculated quickly and easily. The straight-line method can be used as a point of comparison with a more comprehensive and intensive method. One deviation from this method is sometimes for rolling stock which can employ a convex function instead (RAILPAG, 2005). Age is the only consideration in this method (Edgerton, 2009). For the CBAs that use the straight-line depreciation method, different rates of depreciation are used (refer to Table 3).

The difference between costs and benefits as an annuity or in perpetuity is another method sometimes used for calculating RV. The operating period for this method is irrelevant (RAILPAG, 2005). While this method is slightly more robust than straight-line depreciation it still ignores the actual value of the asset and only considers the net of costs minus benefits.

Another position proposes a method of calculating RV for infrastructure by calculating a RV for each infrastructure item and then summing the items to get the total RV (RITES & Silt 2010). This is certainly a more robust calculation than simply assuming one rate for the entire project.

Table 3 reviews of some methods used to calculate RV in the transportation and few other sectors. Assumptions on percentage of total construction budget, discount rate and project lifetime are also presented.

Table 3. Residual Value Methods and Assumptions

RV Method	Infrastructure Sector	% of Total Construction	Discount Rate	Project lifetime	Source
No RV	Freight Transfer Center	No RV due to low discount rate	4%	25 years	Annema et al (2007)
	High Speed Rail	No RV	4%	25 years	Campos et al (2007)
	Road and Transport	No RV	4%	40 years	Annema et al (2007)
		No RV	7% for transport benefits		Annema et al (2007)
	Urban Development	No RV-Infinite lifetime	4%	Infinite	Annema et al (2007)
		No RV-Infinite lifetime	7% for transport and land benefits		Annema et al (2007)
	Waterway Deepening	No RV	3%-4%	25 years	Annema et al (2007)
		No RV	4% with 7% for benefits	Infinite	Annema et al (2007)
Annuity	High Speed Rail		4%	50 years after completion	ACG (2013)
Straight-Line	Airport Extension	a)	4%	38 years	Annema et al (2007)

Freight Rail	35%	4%	35 years	Annema et al (2007)
	40%	4%	35 years	Annema et al (2007)
High Speed Rail	30%	5%	40 years	Campos et al (2007)
	35%	4%	30 years	Campos et al (2007)
	10%	Not used	40 years	Casares and Coto-Milan (2011)
High Speed Rail Link	35%	4%	30 years	Annema et al (2007)
Light Rail		No discount rate[b]	30 years	ACT (2008)
	Fixed Infrastructure		100 years	ACT (2008)
	Earthworks and Drainage		40 years	ACT (2008)
	Stations		50 years	ACT (2008)
	Rail Cars		35 years	ACT (2008)
Port Entrance	Not defined	4%	20, 35, 60 years and no RV	Annema et al (2007)
Port Extension	[a]	4%	30 years	Annema et al (2007)
Rail "Do-minimum" Line Upgrade	20%	3%	40 years	EC, EIB (2005)
Rail Level Crossing Elimination	40%	3%	20 years	EC, EIB (2005)
Rail Line Renewal	10%	5%	38 years	EC, EIB (2005)
Rail Line Upgrade	50%	3%	40 years	EC, EIB (2005)
Rail Link	35%	4%	30 years	Annema et al (2007)
Rail Link to Terminal	50%	5%	65 years	EC, EIB (2005)
Rail Terminal Development	50%	3%	50 years	EC, EIB (2005)

Notes: a) Balance of advantages and disadvantages for last 10 to 15 years of lifetime; b) Used straight line depreciation of actual acquisition costs.

In any case, it is vitally important that the RV component of CBA be clear and transparent so that non-economists, the general public and decision makers can understand and interpret it. RV can be the turning point in a CBA that can change the sign of the net present value (NPV) (Matria, 2012).

5. Discount rate and project lifetime

The lifetime of a project varies by sector and individual project. It begins when the project becomes operational or is opened to service and it ends when it is shut down (Lee Jr., 2002). The time frame ranges from as little as a year to infinity. Highways are usually continually improved giving them an infinite lifetime while equipment is usually salvaged or discarded after a single lifetime. Buildings and vehicles are somewhere in between as they can receive improvements indefinitely or can be salvaged or torn down. When CBA is applied to investments in transportation, project scenario assumptions should be aware that these often have infinite lifetimes (Lee Jr., 2002). Typical project lifetimes for public investment projects can be found in Table 3 (EC, 2008).

Table 3. Average project Lifetime by Infrastructure Sector

Infrastructure Sector	Project Lifetime
Energy	25
Water and Environment	30
Railways	30
Roads	25
Ports and Airports	25
Telecommunications	15
Industry	10
Other Services	15

The discount rate and project lifetime used in the CBA has an enormous impact on the RV. The choice of discount rate can impact whether a project has a positive or negative NPV. Higher discount rates show preference for projects with a lower level of investment or benefits clustered in the short term. Lower discount rates show preference for projects with longer-term returns (EC & EIB, 2005). High discount rates make long-term consequences negligible, which is dangerous if large irreversible environmental damages are part of the CBA (Ludwig, Brock, & Carpenter, 2005). A high exponential discount rate could reduce even a large RV benefit into an insignificant amount especially depending on the project lifetime.

The economic lifetime of an investment project ends when the annual cost of keeping it in service is greater than the annualized cost of replacing it (Mackie & Preston, 1998; Lee Jr., 2002). This culminates in either termination through selling off any still useable assets for their market value or by continuation through continual replacement. This continuation represents the RV (Lee Jr., 2002). Clearly the project lifetime, discount rate and RV are related. A better method for calculating RV rather than simple straight line depreciation is needed.

6. Formulation of a new methodology

By calculating the residual value through its asset components and using more thorough methods to determine discount rates and project lifetimes, a more accurate RV can be included in CBA.

For example, in the case of high-speed rail, calculating RV through its components would include signaling, electrical, catenary, earthworks, structures, track and stations/buildings and their replacement schedules needed. This requires a maintenance and replacement schedule for the components that gives each component a different lifetime. These lifetimes must be synched to the total project lifetime. Depending on these schedules some of the components have a longer lifetime than the project which can increase the RV of the asset over the straight-line depreciation method.

RV encompasses more than just the asset components. It includes land and also materials that can be salvaged during replacement, expansion/upgrades or demolition/sell off. The value of land will likely appreciate over time rather than depreciate. Steel and iron prices fluctuate and can potentially be a source of income during the project lifetime.

Along with material price fluctuations, the risk of new technology such as Maglev reducing the RV to selling off as pieces as scrap should be considered.

The discount rate can have a large impact on the RV as discussed above and a declining or hyperbolic rate should be explored.

7. Conclusion

CBA is examined due to its widespread use as a beneficial decision making tool and because it is also mandated by several institutions for funding. It helps to allocate resources efficiently allowing for the most productive use of scarce financial resources and allowing us to do more with less resources. Although a valuable tool, critical issues in CBA include: uncertainty in traffic forecasts and cost estimates, value of a statistical life (VSL), value of time (VOT) and value of accident; impact of discount rate on NPV; addressing regional and local impacts; disregarding equity; treatment of environmental impacts and lack of thorough methods to estimate the RV.

Properly accounting for the true value that the infrastructure asset generates over time through its residual value will allow for a more accurate CBA and NPV. By calculating the residual value through its asset components and using more thorough methods to determine discount rates and project lifetimes, a more accurate RV can be included in CBA. For example, in the case of high-speed rail, calculating RV through its components would include signaling, electrical, catenary, earthworks, structures, track and stations/buildings and their replacement schedules needed. The value of land and appreciation versus depreciation should be examined as well. The risk of new technology such as Maglev reducing the RV to selling off as pieces as scrap should be included.

Acknowledgements

The authors would like to thank the Portuguese Railway Infrastructure Manager, REFER, E.P.E., for its support and cooperation with the EXPRESS project. The support of the Portuguese Foundation for Science and Technology, FCT and MIT Portugal is also gratefully acknowledged.

References

Annema, J.A., Koopmans, C., & van Wee, B. (2007). Evaluating transport infrastructure investments: The Dutch experience with a standardized approach. *Transport Reviews*, 27(2), 125-150.

ACT (2008). ACT lightrail proposal to Infrastructure Australia. *Australian Capital Territory, Canberra.*

ACG (2013). High speed rail study phase 2 report. *Department of Infrastructure and Transport, Australian Commonwealth Government Canberra*.

Banister, D. (2007). Quantification of the non-transport benefits resulting from rail investment. *2nd International Seminar on Railway Planning, Seoul.*

Banister, D., & Berechman, J. (2000). *Transport investment and economic development*. London: UCL Press.

Bateman, I., Turner, R.K. ,& Bateman, S. (1993). Extending cost benefit analysis of UK highway proposals: Environmental evaluation and equity. *CSERGE Working Paper PA 93-05.*

Beder, S. (2000). Costing the earth: Equity, sustainable development and environmental economics. New South Wales: University of Wollongong.

Bellavance, F., Dionne, G., & Lebeau, M. (2007). The value of a statistical life: A meta-analysis with a mixed effects regression model. *Canada Research Chair in Risk Management, Working Paper 06-12*.

Beukers, E., Bertolini, L., & Te Brommelstroet, M. (2012). Why Cost Benefit Analysis is perceived as a problematic tool for assessment of transport plans: A process perspective. *Transportation Research Part A: Policy and Practice, 46(1), 68-78.*

Bristow, A.L., & Nellthorp, J. (2000). Transport project appraisal in the European Union. *Transport Policy* ,7, 51-60.

Buckley, R. (1991). Auditing the precision and accuracy of environmental impact predictions in Australia. *Environmental Monitoring and Assessment,* 18, 1-23.

Button, K. (1994). Overview of internalizing the social costs of transport. *OECD Internalizing the social costs of transport,* 7-30.

Campos, J., de Rus, G., & Barron, I. (2007). The cost of building and operating a new high speed rail line. *Economic Analysis of High Speed Rail in Europe (2), BBVA Foundation.*

Casares, P. & Coto-Millan, P. (2011). Passenger transport planning. A benefit-cost analysis of the high speed railway: The case of Spain. *Atlantic Review of Economics 2*.

Chester, M., & Horvath, A. (2009). Environmental assessment of passenger transportation should include infrastructure and supply chains. *Environmental Research Letters* 4, 024008.

Chintz, B. (1961). Contrasts in agglomeration: New York and Pittsburgh. *American Economic Review, Papers and Proceedings*, 51(2), 279-289.

Coto-Millan, P., Inglada, V., & Rey, B. (2007). Effects of network economies in high-speed rail: the Spanish case. *Annals of Regional Science,* 41, 911-925.

Culhane, P.J. (1987). The precision and accuracy of U.S. environmental impact statements. *Environmental Monitoring and Assessment,* 8, 217-238.

de Blaeij, A., Florax, R. J.G.M., Rietveld, P., & Verhoef, E. (2007). The value of a statistical life in road safety: A meta-Analysis. *Tinbergen Institute Discussion Paper TI2000-089/3.*

de Silva, H., & Tatam, C. (1996). An empirical procedure for enhancing the impact of road investments. *Transport Policy,* 3(4), 210-211.

Dubgaard, A., Kallesoe, M.F., Petersen, M.L., & Ladenburg, J. (2002). Cost-benefit analysis of the Skjern River Restoration Project. *Department of Economics and National Resources, Royal Veterinary and Agricultural University, Copenhagen.*

Edgerton, D. (2009). Depreciation of infrastructure assets technical information paper. *South Australia Local Government. Brisbane.*

EC (1995). Externalities of fuel cycles “ExternE”. *Project, Report n°2, DGXII, Science, Research and Development, Program Joule, Brussels.*

EC (1997). *The likely macro-economic benefits and employment impacts of investments in trans-european transport network.* Brussels: European Commission.

EC (2006). *Guidance on the methodology for carrying out cost-benefit analysis.* Brussels: European Commission.

EC (2008). Guide to cost-benefit analysis of investment projects. Brussels: European Commission.

EC and EIB (2005). Rail project appraisal guidelines (RAILPAG). Brussels and Luxembourg: European Commission & European

Investment Bank.

Farber, D.A., & Hemmersbaugh, P.A. (1993). The shadow of the future: discount rates, later generations, and the environment. *Vanderbilt Law Review*, 46, 267-304.

Feitelson, E. (2002). Introducing environmental equity dimensions into the sustainable transport discourse: issues and pitfalls. *Transportation Research Part D,* 7, 99-118.

Florio, M. (2006a). Cost-benefit analysis and incentives in infrastructure planning and evaluation: A research agenda for the EU cohesion policy. *5th Milan European Economy Workshop, Milan.*

Florio, M. (2006b) – Cost-benefit analysis and the European Union Cohesion Fund: On the social cost of capital and labour. *Regional Studies,* 40(2), 211-224.

Florio, M., & Vignetti, S. (2003). Cost-benefit analysis of infrastructure projects in an enlarged European Union: an incentive-oriented approach. *Departmental Working Papers 13.2003, Department of Economics, Business and Statistics, Universita degli Studi di Milano.*

Flyvbjerg, B. (2005). Policy and planning for large Infrastructure projects: problems, causes, cures. *World Bank Policy Research Working Paper 3781.*

Flyvbjerg, B., Bruzelius, N., & Rothengatter, W. (2003). *Megaprojects and risk: an anatomy of ambition*. Cambridge: Cambridge University Press.

Flyvbjerg, B., Skamris Holm, M.K, & Buhl, S.L. (2004). What causes cost overrun in transport infrastructure projects? *Transport Reviews,* 24(1), 3-18.

Gerrod, G., & Willis, K.G. (1999). *Economic valuation of the environment, methods and case studies.* Cheltenham: Edward Elgar.

Gijsen, A., & van der Brink, R.M.M. (2002). Het spoor in model: energiegebruik en emissies door het railvervoer. Beschrijving en toepassing van het model PRORIN. *National Institute for Public Health and the Environment, Bilthoven*.

Grant-Muller, S.M., Mackie, P., Nellthorp, J., & Pearman, A. (2001). Economic appraisal of European transport projects: the state-of-the-art revisited. *Transport Reviews: A Transnational Transdisciplinary Journal*.

Guhnemann, A. (1999). SEA and sustainable development in the Baltic Sea region. OECD/ECMT Conference on Strategic Environmental Assessment for Transport. Warsaw.

Gwilliam, K.M. (1997). The value of time in economic evaluation of transport projects: Lessons from recent research. *Infrastructure Notes, Transport Sector, Transport No. OT-5, The World Bank.*

Hanley, N., & Spash, C.L. (1993). *Cost-benefit analysis and the environment.* Cheltenham: Edward Elgar.

Heinzerling, L., & Ackerman, F. (2002). Pricing the priceless. Cost-Benefit Analysis of environmental protection. *Georgetown Environmental Law and Policy Institute, Georgetown University Law Center*.

Hewings, G.J.D. (1978). The trade-off between aggregate national efficiency and interregional equity: Some recent empirical evidence. *Economic Geography*, 54(3), 254-263.

International Accounting Standards Board (IASB) (2006). D12 – *Service concession arrangements – significance of residual value. Agenda Paper 5(iii), London.*

International Transport Forum (ITF) (2011). Improving the practice of cost benefit analysis in transport. *Discussion Paper No. 2011-1*.

Laird, J.J., Nellthorp, J., & Mackie, P.J. (2005). Network effects and total economic impact in transport appraisal. *Transport Policy,* 12(6), 537-544.

Layard, R., & Glaister, S. (2003). *Cost-Benefit Analysis 2nd Edition.* Cambridge: Cambridge University Press.

Lee Jr., D.B. (2002). Fundamentals of life-cycle cost analysis. *Transportation Research Record*, 1812, 203-210.

Ludwig, D., Brock, W.A., & Carpenter, S.R. (2005). Uncertainty in discount models and environmental accounting. *Ecology and Society,* 10(2), 13.

Mackie, P., & Preston, J. (1998). *Twenty-one sources of error and bias in transport appraisal. Transport Policy, 5, 1-7.*

Mackie, P.J., Wadman, M., Fowkes, A.S., Whelan, G., Nellthorp, J., & Bates, J. (2003). Values of travel time savings UK. *Institute of Transport Studies, University of Leeds, Working Paper 567*.

Mairate, A., & Angelini, F. (2006). Cost-benefit analysis and EU Cohesion Policy. *5th Milan European Economy Workshop, Milan*.

Martens, K. (2011). *Substance preceeds methodology: on cost-benefit analysis and equity. Transportation,* 38, 959-974.

Martinez, L.M. (2010) – Financing public transport infrastructure using the value capture concept. *PhD Thesis, Transportes, Universidade Tecnica de Lisboa, Instituto Superior Tecnico.*

Masser, I., Sviden, O., & Wegener, M. (1993). Transport planning for equity and sustainability. *Transportation Planning and Technology,* 17, 319-330.

Matria, T. (2012). Cost benefit analysis and ex-post evaluation of railway upgrade projects Ex-post economic evaluation, evaluation of traffic disturbance during construction and evaluation of travel time variability. *MsC Thesis,* Transportes, Universidade Tecnica de Lisboa, Instituto Superior Tecnico.

Mayer, M.L.J., & McGoey-Smith, A.D. (2006). Risk-based cost and schedule estimation for large transportation projects. *European Transport Conference 2006, Strasbourg*.

Mera, K. (1967). Tradeoff between aggregate efficiency and interregional equity: A static analysis. *The Quarterly Journal of Economics,* 81(4), 658-674.

Miller, T.R. (2000). Variations between countries in values of statistical life. *Journal of Transport Economics and Policy,* 34(2), 169-188.

Mishan, E.J., & Quah, E. (2007). Cost-benefit analysis (5th ed). New York: Routeledge.

Mouter, N., Annema, J.A., & van Wee, B. (2011). Current issues in the Dutch CBA practice. CTS Workshop on Contemporary Issues in CBA in the Transport Sector, Stockholm.

Mrozek, J.R., & Taylor, L.O. (2002). What determines the value of life? A meta-analysis. *Journal of Policy Analysis and Management,* 21(2), 253-270.

Munger, M. (2000). Analyzing policy: choices, conflicts and practices. New York: W.W. Norton.

Nash, C.A. (1991). The case for high speed rail. Institute of Transport Studies, University of Leeds. Working Paper 323.

Nickel, J., Ross, A.M., & Rhodes, D.H. (2009). Comparison of project evaluation using cost-benefit analysis and multi-attribute tadespace exploration in the transportation domain. *Second International Symposium on Engineering Systems, MIT, Cambridge*.

Niemeyer, S.C., & Spash, L. (2001). Environmental valuation analysis, public deliberation, and their pragmatic syntheses: a critical appraisal. *Environment and Planning C: Government and Policy,* 19, 567-585.

Ninan, K.N. (2008). *Cost-benefit analysis: An introduction*. Santa Barbara: Donald Bren School of Environmental Science and Management, University of California.

Odgaard, T., Kelly, C.E., & Laird, J. (2006). Current practice in project appraisal in Europe. *Deliverable 1 of the HEATCO project.*

OECD (1969). *Manual of industrial project analysis. Volume II. Social cost-benefit analysis. Paris: OECD.*

Pearce, D.W., Mourato, S., & Atkinson, G. (OECD) (2006). *Cost-benefit analysis and the environment: recent developments.* Paris: OECD.

Persky, J. (2001). Cost-Benefit Analysis and the classical creed. *Journal of Economic Perspectives,* 15(4), 199-208.

Quinet, E., & Vickerman, R. (2004). *Principles of Transport Economics*. Cheltenham: Edward Elgar Publishing.

Rainey, D. (1997). Value of travel time savings. *Austroads, Haymarket NSW*.

Rasouli, S., & Timmermans, H. (2012). Uncertainty in travel demand forecasting models: literature review and research agenda. *Transportation Letters: The International Journal of Transportation Research*, 4, 55-73.

Richardson, H. (1979). Chapter 7. In Folmer, H. (Ed.)*, Spatial Inequalities and Regional Development: Aggregate efficiency and intergenerational equity* (pp. 161-184). Dordrecht: Klewer.

Rietveld, P. (1989). Infrastructure and regional development: A survey of multiregional economic models. The Annals of Regional *Science,* 23, 255-274.

RITES India Ltd., & Silt Consultants Pvd. (2010). Feasibility study of Mechi-Mahakali and Pokhara-Kathmandu Electric Railway. *Government of Nepal, Ministry of Physical Planning and Works, Kathmandu*.

Salling, K.B., & Banister. D. (2009).Assessment of large transport infrastructure projects: The CBA-DK model. *Transportation Research Part A*, 43, 800-813.

Shi, J., & Wu, Z. (2010). A quantitative transportation project investment evaluation approach with both equity and efficiency aspects. *12th WCTR, Lisbon.*

Sieber, N. (2001). Spatial and federal transport panning in Germany: How to implement spatial planning goals into federal transport plans. 9th *World Confrence on Transport Research, Seoul*.

Skamris, M.K., & Flyvbjerg, B. (1997). Inaccuracy of traffic forecasts and cost estimates on large transport projects. *Transport Policy*, 4(3), 141-146.

Theodoropoulos, S., & Tassopoulos, E. (2011). Alternative model for the selection of the preferred bidder in concession projects. University of Piraeus Department of Maritime Studies, Piraeus.

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, 351-359.

Trottenberg, P., & Rivkin, R. (2011). Treatment of the economic value of a statistical life in departmental analyses-2011 Interim Adjustment. *U.S. Department of Transportation, Office of the Assistant Secretary for Transportation Policy.*

United Nations Industrial Development Organization (1972). *Guidelines for project evaluation.* New York: United Nations.

van Wee, B. (2007). Rail infrastructure: challenges for cost-benefit analysis and other ex ante evaluations. *Transportation Planning and Technology*, 30(1), 31-48.

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, 1-7.

van Wee, B., van der Brink, R., & Nijland, H. (2003). Environmental impacts of high-speed rail links in cost-benefit analyses: a case study of the Dutch Zuider Zee line. *Transportation Research Part D,* 8, 299-314.

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, 598-610.

Vining, A.R., & Boardman, A.E. (2005). *Policy analysis in Canada: The state of the art.* Toronto: University of Toronto Press.

Weitzman, M.L. (1994). On the environmental discount rate. Journal of Environmental Economics and Management 36:201-208.

Weitzman, M.L. (1998). Why the far-distant future should be discounted at its lowest possible rate. *Journal of Environmental Economics and Management*, 26, 200-209.

Weitzman, M.L. (2001). Gamma discounting. *The American Economic Review*, 91, 260-271.

Wood, C., Dipper, B., & Jones, C. (2000). Auditing the Aassessment of the environmental impacts of planning projects. *Journal of Environmental Planning and Management,* 43(1), 23-47.

World Bank (1975). *Economic analysis of projects*. Washington DC: World Bank.

World Bank (2004). *Monitoring and evaluation: Some tools, methods and approaches.* Washington DC: World Bank.

World Bank (2005a). Demand forecasting errors. *Transport Note No. TRN-12.*

World Bank (2005b). Valuation of accident reduction. *Transport Note No. TRN-16.*

World Bank (2005c). Valuation of time savings. *Transport Note No. TRN-15.*