Transport infrastructure evaluation using cost-benefit analysis: improvements to valuing the asset through residual value - a case study

Submitted on the 31 of July 2013
For the 93rd Annual Meeting of the Transportation Research Board, January 2014
Number of words: 5831+1250=7081
Number of tables: 5
Number of figures: 0

Heather Jones[1]

CESUR, Center for Urban and Regional Systems, Department of Civil Engineering, Architecture and Georesources, Instituto Superior Técnico, University of Lisbon, Av. Rovisco Pais n°1, 1049–001 Lisbon, Portugal.

Tiago Domingos

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.

Filipe Moura

CESUR, Center for Urban and Regional Systems, Department of Civil Engineering, Architecture and Georesources, Instituto Superior Técnico, University of Lisbon, Av. Rovisco Pais n°1, 1049–001 Lisbon, Portugal.

Joseph Sussman

JR East Professor, Civil and Environmental Engineering and Engineering Systems, Massachusetts Institute of Technology, 77 Massachusetts Ave., Cambridge, MA 02139.

[1] Corresponding Author

ABSTRACT
This paper addresses major weaknesses of cost-benefit analysis (CBA). We make a comprehensive review of methodologies used in representative case studies and identify the critical factors of CBA. These include traffic forecasts, cost estimates, residual value, discount rate, value of non-market goods, regional and local impacts, environmental impacts and equity. We conclude that some critical factors have received more attention and research than others but none of the factors are yet solved and further investigation is crucial until solutions are universally accepted. 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. We propose three methods for calculating RV: straight-line depreciation, annuity/perpetuity and component. We conclude that the component method is the most complete method, and that RV is more important in situations where its value is compared to the total costs and benefits such as production facilities or when the benefit-cost ratio is close to 1.

Keywords: Cost benefit analysis, transport infrastructure, residual value, discount rate

INTRODUCTION

Cost Benefit Analysis (CBA) is the most widely used evaluation framework (*1, 2, 3*). It is used because it is a comprehensive evaluation tool (*1, 4, 5*), it may lead to efficient allocation of resources (*6, 7, 8*), and it accounts for both costs and benefits (*4, 6, 8, 9, 10, 11*). However, currently and in practice, the most compelling reason for its use is that many governments and agencies require CBA for final approval of projects. For European Union (EU) member states, CBA is required for funding from the Instrument for Pre-Accession countries, Cohesion Fund or Structural Funds. The U.S., Canada and Netherlands require CBA for infrastructure projects. The OECD (*12*), UN (*13*) and World Bank (*14*) use CBA as part of their funding process mechanism. The United Nations (UN) requires CBA for financial support applications (*15*).

As global population growth inherently increases demand on transport infrastructure, and with the size of projects soaring, properly evaluating the costs and benefits of the investment is required for the most efficient use of scarce funding resources (*6, 7, 8*). Some impacts are adequately covered by CBA while others leave areas for improvement. The main objectives of this paper are: firstly, to make a comprehensive review of methodologies used in representative case studies of CBA and identify the critical factors; and, secondly, to analyze more in depth the treatment of infrastructure's residual value (RV), after concluding that current practice is inadequate and needs further research. For the latter, we compare three methods for calculating RV and discuss the results suggesting improvements for CBA practice for this matter.

MAJOR WEAKNESSES OF COST BENEFIT ANALYSIS

CBA has been called the "*single most important problem-solving tool in policy work*" (*1*). 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 (*2*). CBA weighs the pros and cons of a project or policy in a rational and systematic process. It 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) (*4, 8, 16*). Decision makers must assess who are the gainers and losers across both space and time (*8*). It ensures that the net aggregate benefits to society outweigh the net aggregate costs (*2*). Therefore, it monetizes both inputs and outputs. This monetization is founded on a valuation system that transforms the inputs into a monetary value using actual or shadow prices (*11*) that expresses (given certain assumptions) social welfare that should then be maximized (*9*). It explicitly states economic assumptions so they are not overlooked or remain implicit (*6*), including externalities, thus integrating economic and environmental considerations into decision making (*10*). It also includes accounting for time through the use of a discount rate (*1, 8*). In a nutshell, 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 (*2*).

The critical factors of current practice here presented were identified and analyzed based on the literature except for residual value and absence of lifecycle impacts which were identified by the authors.

CBA has been criticized on many fronts such as its decision making process (*17, 18*), its monetization of non-market goods (*19, 20*), its non-accounting for equity (*21*), the openness of the interpretation of its results (*6*), its scrutiny by the public (*22*), its need for completeness and correctness (*23*), its lack of being understood (*24*), its ethics (*25*) and its discounting of long-term environmental consequences (*26*).

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" (*27*). 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. 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 (*20, 23, 24*). For the purpose of this study we will focus on the inputs and their calculations currently used in practice 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 as Practiced

Factor	Weakness	Authors
Traffic Forecast	Commonly off by 20%-60% (usually overestimated)	Skamris & Flyvbjerg, 1997 (28); Flyvbjerg, Bruzelius, & Rothengatter, 2003 (29); Flyvbjerg, 2007 (30); World Bank, 2005a (31); Mayer & McGoey-Smith, 2006 (32); van Wee, 2007 (25); Salling & Banister, 2009 (33); Rasouli & Timmermans, 2012 (34)
Cost Estimation	Overruns of 50%-100% are not uncommon (usually underestimated)	Skamris & Flyvbjerg, 1997 (28); Flyvbjerg, Bruzelius, & Rothengatter, 2003 (29), Flyvbjerg, Skamris Holm, & Buhl, 2004 (35); Flyvbjerg, 2007 (30); Mayer & McGoey-Smith, 2006 (32); van Wee, 2007 (25); Salling & Banister, 2009 (33); Rasouli & Timmermans, 2012 (34)
Discount Rate	Impossible to forecast long-term. Higher rates favor smaller investment or short term benefits	Farber & Hemmersbaugh, 1993 (36); Weitzman, 1994 (37); Weitzman, 1998 (38); Weitzman, 2001 (39); Florio & Vignetti, 2003 (40); RAILPAG, 2005 (41); EC, 2008 (16)
Value of Life	Hard to determine, no agreement on method or value	Farber & Hemmersbaugh, 1993 (36); Gerrod & Willis, 1999 (42); Miller, 2000 (43); Mrozek & Taylor, 2002 (44); Quinet & Vickerman, 2004 (45); de Blaeij, Florax, Rietveld, & Verhoef, 2003 (46); Trottenberg & Rivkin, 2011 (47)
Safety	Wide agreement on method and value. Developing countries have some difficulty	Grant-Muller, Mackie, Nellthorp, & Pearman, 2001 (48); World Bank, 2005b (49)
Value of Time	Complex procedure, no consensus on which variables are relevant and relationships among values	Rainey, 1997 (50); Gwilliam, 1997 (51); Mackie & Preston, 1998 (19); Gerrod & Willis, 1999 (42); Banister & Berechman, 2000 (21); World Bank, 2005c (52); van Wee, 2007 (25); Trottenberg and Rivkin,. 2011 (47)
Regional Impacts	Does not account for network or crowding out effects	Rietveld, 1989 (53); Banister & Berechman, 2000 (21); Sieber, 2001 (54); Vickerman, 2007 (55); Flyvbjerg, Bruzelius, & Rothengatter, 2003 (29), Mairate & Angelini, 2006 (56); Coto-Millan, Inglada, & Rey, 2007 (57); van Wee, 2007 (25); ITF, 2011 (5)
Local Impacts	Does not account for agglomeration and land use interaction	Chintz, 1961 (58); van Wee, 2007 (25); Martinez and Viegas, 2009 (59)

Equity	Not included in CBA. Monetization not universally accepted.	Mera, 1967 (60); Hewings, 1978 (61); Richardson, 1979 (62); Masser, Sviden, & Wegener, 1993 (63); Banister & Berechman, 2000 (21); Beder, 2000 (10); Feitelson, 2002 (64); Persky, 2001 (22); Heinzerling & Ackerman, 2001 (24); Annema Koopmans, & van Wee, 2007 (23); Ninan, 2008 (8); Thomopoulos, Grant-Muller, & Tight, 2009 (65); Shi & Wu 2010 (66), Martens, 2011 (67)
Environmental Impacts	Difficult to monetize with large uncertainty ranges. LCA is not performed, thus not accounting for impacts from construction and maintenance of infrastructure	Wood, Dipper, & Jones, 2000 (68); Banister & Berechman 2000 (21); Niemeyer & Spash, 2001 (20); Heinzerling & Ackerman, 2001 (24); Flyvbjerg, Bruzelius, & Rothengatter, 2003 (29), van Wee, van der Brink, & Nijland, 2003 (69); Laird, Nellthorp, & Mackie, 2005 (70); Chester & Horvath, 2007 (71); van Wee, 2007 (25)
Residual Value	Often overlooked. No agreement on methodology.	Lee Jr., 2002 (72); Florio & Vignetti, 2003 (40); RAILPAG, 2005 (41); EC, 2008 (16); IASB, 2006 (73); Edgerton, 2009 (74); Matria, 2012 (75)

Some inroads have been made in addressing 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, value of life, safety and value of time. Others need considerable advances, e.g., 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.

RESIDUAL VALUE

Residual value (RV) is an important component of CBA and it represents the infrastructure's value at the end of its projected lifetime. It is accounted for as a in the final year of the CBA and 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, RV is overlooked during CBA, which artificially depresses the projects returns (*40*). As such, current methods for calculating RV do not properly reflect the value that the asset generates after the end of the project's lifetime.

The RV of the project investment 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 of the project. The discounted value of every net future receipt after the time horizon should be included, making it the same as the liquidation value (*16*).

However, it is often calculated differently in practice, as the present value (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 (*16*). 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 (*73, 74*). 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.

RV is often ignored in transportation CBAs. Table 2 presents some references on how RV has been approached for transportation infrastructures. RV is of particular importance in concessionaire situations. It can indirectly stipulate the quality of service and the state and functionality of the infrastructure at the end of the concession period. Infrastructure projects with large hazardous wastes or cleanup costs can have a negative RV. A prime example is the decommissioning costs for a nuclear power plant, usually quite considerable.

TABLE 2 Residual Value in Transportation Infrastructure Literature

Source	Position
Lee Jr., 2002 (72)	Some investments continue infinitely and should have a RV calculated for them
EC, 2008 (16)	Economic life of the project and RV for any useful assets after time horizon
Odgaard, Kelly, and Laird, 2006 (76)	RV is composed of the lifetime of the infrastructure and the depreciation profile. The treatment varies by country
Campos, de Rus, and Barron, 2007 (77)	RV is difficult to calculate because rail has different assets with different useful lives and depreciation rates
23 Annema Koopmans, and van Wee, 2007 (23)	Actual RV calculations by Dutch CBA for infrastructure projects from 2000-2006
41 EC and EIB RAILPAG, 2005 (41)	RV should be calculated individually for the different components
ACT, 2008 (78)	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 (79)	RV is calculated for each infrastructure item

Residual Value Concepts

Depreciation

Depreciation measures and spreads over time the costs associated with consuming an asset over its useful life. It is the systematic allocation of the depreciable amount of an asset over its useful life. The depreciable amount is the cost of an asset less its residual value (or, equivalently, the residual value of an asset is equal to its cost minus its depreciable amount). Useful life is the period over which an asset is expected to be available for use by an entity (*80*). Since depreciation concerns using up an asset the method used should reflect the pattern in which it is being used. Technical and commercial obsolescence such as potential changes in consumer demand should be taken into account in this regard. Physical life is the potential service life of an asset before it physically becomes unable to produce a good or service. The terms economic and useful and life can be used interchangeably (*16*).

Depreciation is typically calculated in one of three ways. The first and most commonly used method is straight-line; it uses only age of the asset and assumes that consumption of the asset is constant. The second method is condition based. It uses only the physical condition of the asset. It is most commonly used when evaluating road pavement by creating a degradation profile that correlates the physical condition to an estimated total life cycle. The last method is consumption based which uses the assets' remaining service potential after taking into account both aggregate and component specific factors.

Discount Rate and Project Lifetime

The lifetime of a project varies by sector and individual project. It begins when the project becomes operational and it ends when it is shut down (*72*). The time frame ranges from as little as a year to infinity. Highways are usually continually improved giving them an effectively infinite lifetime while equipment is usually salvaged or discarded after a given time period. Buildings and vehicles are somewhere in between as they can receive improvements indefinitely or can be salvaged or torn down.

The discount rate and project lifetime used in CBA can impact whether a project has a positive or negative Net Present Value (NPV). A high exponential discount rate could reduce even a large RV benefit into an insignificant amount especially depending on the project lifetime. The discount rate can have a large impact on the RV and a declining (hyperbolic) rate should be explored. The use of different and potentially hyperbolic discount rates for each cost and benefit will be further researched by the authors. Items with high uncertainty such as revenues should have high discount rates while items with more certainty such as RV should have lower rates and items with long reaching effects such as environmental impacts should have very low rates.

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 (*19, 72*). This culminates in either termination through selling off any still useable assets for their market value or by continuation through continual replacement.

METHODS TO CALCULATE RESIDUAL VALUE

Straight-Line Depreciation Method

In order to simplify calculations, straight-line depreciation is the most commonly used method for calculating RV (*82*) where 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. Although it is not the best nor the most comprehensive method, it can be calculated quickly and easily and it can be used as a point of comparison with a more comprehensive and intensive method. Age is the only consideration in this method (74). For CBAs that use the straight-line depreciation method, different rates of depreciation are used (Table 3). It is calculated from the remaining service life (RSL) as:

$$RV = \frac{RSL}{total\ service\ life} * initial\ capital\ cost$$

Table 3 reviews some methods used to calculate RV in transportation and a 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	(23)
	High Speed Rail	No RV	4%	25 years	(77)
	Road and Transport	No RV	4%	40 years	(23)

		No RV	7% for transport benefits		(23)
	Urban Development	No RV-Infinite lifetime	4%	Infinite	(23)
		No RV-Infinite lifetime	7% for transport and land benefits		(23)
	Waterway Deepening	No RV	3%-4%	25 years	(23)
		No RV	4% with 7% for benefits	Infinite	(23)
Annuity	High Speed Rail		4%	50 years after completion	(82)
Straight-Line	Airport Extension	[a)]	4%	38 years	(23)
	Freight Rail	35%	4%	35 years	(23)
		40%	4%	35 years	(23)
	High Speed Rail	30%	5%	40 years	(77)
		35%	4%	30 years	(77)
		10%	Not used	40 years	(83)
		24%	5%	35 years	(84)
	High Speed Rail Link	35%	4%	30 years	(23)
	Light Rail		No discount rate[b)]	30 years	(78)
		Fixed Infrastructure		100 years	(78)
		Earthworks and Drainage		40 years	(78)
		Stations		50 years	(78)
		Rail Cars		35 years	(78)
	Port Entrance	Not defined	4%	20, 35, 60 years and no RV	(23)
	Port Extension	[a)]	4%	30 years	(23)
	Rail "Do-minimum" Line Upgrade	20%	3%	40 years	(41)
	Rail Level Crossing Elimination	40%	3%	20 years	(41)
	Rail Line Renewal	10%	5%	38 years	(41)
	Rail Line Upgrade	50%	3%	40 years	(41)
	Rail Link	35%	4%	30 years	(23)
	Rail Link to Terminal	50%	5%	65 years	(41)
	Rail Terminal Development	50%	3%	50 years	(41)

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

Annuity and Perpetuity Methods

The difference between discounted costs and benefits, after the end of the project, as an annuity or in perpetuity is another method sometimes used for calculating RV. This method ignores the actual value of the asset and only considers the net of costs minus benefits. Some critics argue against this method as it presumes a steady state where expenditures on the asset are not necessarily recognized as enhancing the future economic benefits of the asset (*80*).

The annuity version is chosen for assets that have a specific lifetime that is past the project time period (e.g. 40 years lifetime for a project that is evaluated for 30 years would have a 10 year annuity). To determine the RV using the annuity method the difference between the costs and benefits are discounted over the difference between the useful life and the physical life of the asset. It is calculated as:

$$PV = C \times \left[\frac{1-(1+i)^{-n}}{i}\right]$$

Where the present value (PV) equals the cash flow (C) which is the net of benefits and costs, *i* is the discount rate and *n* is the number of payments (years).

The perpetuity method would be used for projects that are assumed to have an infinite lifetime such as one that can be prolonged by maintaining it. The operating period for the perpetuity method is irrelevant (*41*). It is calculated as:

$$PV = \frac{C}{(1+r)^1} + \frac{C}{(1+r)^2} + \frac{C}{(1+r)^3} \cdots = \frac{C}{r}$$

Where the present value (PV) equals the cash flow (C) (or coupon) which is the net of benefits and costs and *r* is the discount rate. The perpetuity method is equal to the limit of the annuity method when *n*, the number of periods, goes to infinity.

Component Method

Another method of calculating RV for infrastructure is by calculating a RV for each infrastructure item and then summing the items to get the total RV (*79*). This is certainly a more robust calculation than simply assuming one rate for the entire project. 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. This is effectively a modified consumption based depreciation method.

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 required replacement schedules. 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. Table 4 refers to the recommended rate of residual value for components (*79*).

TABLE 4. Residual Value of Infrastructure Items

Infrastructure Item	Rate of Residual Value (after 30 years)	Total Lifetime (years)
Land and Associated Activities	80%	150
Earthwork	50%	60
Protection Works	50%	60
Blanketing	50%	60
Bridges	50%	60
P. Way	20%	38
Station and Buildings	50%	60
Tunnels	50%	60
Electrical	30%	43
S and T	20%	38
Maintenance Facilities (Electrical and	40%	50

Mechanical)

Source: *79*

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 often appreciate over time. Steel and iron prices fluctuate and can potentially be a source of income during the project lifetime. The risk of new technology such as Maglev making the investment obsolete and reducing the RV to only selling off the pieces as scrap should be considered.

CASE STUDY

For the Portuguese case study the HSR CBA from Rede Ferroviária de Alta Velocidade (*84*) will be used and will be referred to as Portuguese High Speed Rail (PHSR) so as not to confuse it with a general CBA. In order to calculate the costs and benefits for the CBA, the difference between the "Do-Minimum" (DM) and "Do-Something" (DS) was used by RAVE and represents the data used. Data for "Do-Nothing" was not available. All values for RV and NPV are in thousands.

The DM alternative includes the high speed (HS) links between Lisbon and Madrid and between Porto and Vigo. The DS alternative includes those two links plus a HS link between Lisbon and Porto. Since the only difference is the HS link between Lisbon and Porto, these are the only values that need to be determined.

The PHSR has 5 years of construction followed by 35 years of operation. The CBA uses a discount rate of 5%. The RV was assumed to be 24% of the initial construction investment. The RV was €934,877 and NPV was €3,047,785. The authors also calculated the NPV at a discount rate of 8.5% which resulted in €670,330.

For comparison purposes NPV was calculated using €0 for RV and 5% and 8.5% as the discount rate. NPV was €2,927,336 and €639,942 respectively.

Annuity and Perpetuity Results

In order to use the annuity method the physical lifetime is estimated to be 50 years. The RV is the difference between costs and benefits for the period after the project lifetime and the end of the physical lifetime. The future costs and benefits for a period of 15 years after the 35 year lifetime were estimated to be a constant annuity stream. A physical lifetime of 50 years is reasonable as many of the conventional tracks that are being used in Europe and the U.S. were built 150 years ago and maintained over that period as well. The discount rate was kept at the same 5% that was used in the study and also a new interest rate was constructed. The new interest was calculated by using the risk free rate represented by the average 10 year German bond over the last 20 years (4.4%) plus the Beta for the rail sector (0.55) multiplied by the market risk premium (11.9% average 20 year DAX return minus the risk free rate 4.4%=7.5%) which equals 8.5%. Using the 5% discount rate the RV is €8,303,421 and NPV is €3,997,145. Both the RV and NPV are higher than using the original method. At 8.5%, RV is €6,643,145 and NPV is €855,877.

In order to use the perpetuity method the difference between costs and benefits in the final year were assumed to be constant as a reflection of business as usual by that time. Both the 5% and 8.5% discount rates were used. At 5%, RV is €15,999,412 and NPV is €4,988,412. As expected both RV and NPV are higher than the original method and the annuity method. At 8.5%, RV is €9,411,419 and NPV is €945,860.

Component Method Results

The RV was calculated using the different lifetimes and depreciation rates for each of the components. The component lifetimes were determined using both the RITES and Silt (*79*) and RAILPAG (*41*) guidelines. RV was calculated using three different sets of assumptions.

Scenario 1 assumed that land did not depreciate and was worth the same as its initial investment. The track was assumed to depreciate at a normal rate with a lifetime of about 40 years (plus repair and renovation investments increasing the value) and that there was a market for the asset at the end of the appraisal period. This resulted in RV of €2,674,124 and NPV of €3,271,869 at 5% and €726,864 at 8.5%.

Scenario 2 included the land appreciating to twice the initial investment. It also included the same assumptions about the track as in Scenario 1 above but and also that the materials prices made it worth about the initial investment. It also assumed that there was a market for the investment. This resulted in RV of €3,191,719 and NPV of €3,338,555 at 5% and €743,689 at 8.5%.

The last scenario assumed that there was not a market for the asset (Maglev or new technology being the only investments made). The land and some materials have some value bringing the RV to €1,155,747 and NPV to €3,076,242 at 5% and €677,509 at 8.5%.

TABLE 5. Residual Value and Net Present Value by Method

Method	Pros	Cons	RV (in €000s)	NPV 5% (in €000s)	RV (in €000s)	NPV 8.5% (in €000s)
Omitted	Easiest, very fast	Gives no remaining value to the asset unjustified	0	2,927,336	0	639,942
Straight-Line	Simple, quick	Typically uses a % of total construction cost rather than real value	934,877	3,047,785	934,877	670,330
Annuity	Reflects difference of costs and benefits for difference between economic and useful life	Ignores actual value of asset	8,303,421	3,997,145	6,643,145	855,877
Perpetuity	Reflects difference of costs and benefits as if economic life is infinite	Ignores actual value of asset	15,999,412	4,988,412	9,411,419	945,860
Component	Gives actual value of physical asset at end	More difficult to calculate	2,674,124	3,271,869	2,674,124	726,864

	of project appraisal

CONCLUSION

Properly accounting for RV is a key element when performing CBA (*85*). The authors believe that the component method most accurately reflects the true value of the asset as it shows what each component is worth at the end of the appraisal period. It also takes into account the value of land and the prices of materials. Table 7 presents the results for each of the methods used. As expected, the perpetuity method has the highest RV and NPV. The component method is more detailed and produces a higher RV and NPV than the straight line method. In the end, it also makes the accounting procedure more transparent and might bring positive contributions for the purpose of contract negotiation (e.g., PPP's) since breaking down the cost structure of RV is more defensible than making bundled assumptions for the infrastructures' RV, as is the case of straight-line depreciation or some % of initial cost.

In this case study, changing the value of the RV did not change the final result of the cost benefit analysis. In other situations where RV value represents a high percent of the total costs and benefits such as hazardous waste facilities it can change the sign of the NPV (*75, 85*).

After performing numerous sensitivity analyses on demand, the discount rate and construction costs, the authors concluded that RV has a larger impact when the benefit to cost ratio is closer to 1. When the ratio is near 1, the order of magnitude or exclusion of the RV has the ability to change the sign of the NPV.

REFERENCES

(1) Munger, M. *Analyzing Policy: Choices, Conflicts and Practices*. W.W. Norton, New York, 2000.
(2) Nickel, J., Ross, A.M. and Rhodes, D.H. Comparison of Project Evaluation Using Cost-Benefit Analysis and Multi-Attribute Tradespace Exploration in the Transportation Domain. Presented at Second International Symposium on Engineering Systems, MIT, Cambridge, 2009.
(3) Valentin, M., Ioan, P.M., Andrei, P. and Delia, G. Methodological Approaches in Realizing and Applying Cost-Benefit Analysis for the Investment Projects. *Annals of Faculty of Economics,* Vol. 2, No. 1, 2009, pp. 156-162.

(4) Pearce, D.W., Mourato, S. & Atkinson, G. (OECD) (2006). *Cost-Benefit Analysis and the Environment: Recent Developments.* The Organisation for Economic Co-operation and Development, Paris, 2006.

(5) *Improving the Practice of Cost Benefit Analysis in Transport. Discussion Paper No. 2011-1*. International Transport Forum, 2011.
(6) *Monitoring and Evaluation: Some Tools, Methods and Approaches*. World Bank, 2004
(7) Ackerman, F. Critique of Cost-Benefit Analysis, and Alternative Approaches to Decision-Making. A report to Friends of the Earth England, Wales and Northern Ireland, London, 2008.
(8) Ninan, K.N. *Cost-Benefit Analysis: An Introduction*. Donald Bren School of Environmental Science and Management, University of California, Santa Barbara, 2008.

(9) Guhnemann, A. SEA and Sustainable Development in the Baltic Sea Region. Presented at OECD/ECMT Conference on Strategic Environmental Assessment for Transport. Warsaw, 1999.
(10) Beder, S. Costing the Earth: Equity, Sustainable Development and Environmental Economics. *New Zealand Journal of Environmental Law*, Vol. 4, 2000, pp. 227-243.
(11) Vining, A.R. and Boardman, A.E. *Policy Analysis in Canada: The State of the Art.* University of Toronto Press, Toronto, 2005.

(12) *Manual of Industrial Project Analysis. Volume II. Social Cost-Benefit Analysis.* The Organisation for Economic Co-operation and Development, Paris, 1969.
(13) *United Nations Industrial Development Organization. Guidelines for project evaluation.* United Nations, 1972.
(14) *Economic Analysis of Projects*. World Bank, 1975.

(15) Mishan, E.J. and Quah, E. *Cost-Benefit Analysis 5th edition.* Routeledge, New York, 2007.
(16) *Guide to Cost-Benefit Analysis of Investment Projects*. European Commission, 2008.
(17) Mouter, N., Annema, J.A. and van Wee, B. Current Issues in the Dutch CBA Practice. Presented at CTS Workshop on Contemporary Issues in CBA in the Transport Sector, Stockholm, 2011.
(18) Beukers, E., Bertolini, L. and Te Brommelstroet, M. 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*, Vol. 46, No. 1, pp. 68-78.

(19) Mackie, P. and Preston, J. Twenty-One Sources of Error and Bias in Transport Appraisal. *Transport Policy*, Vol. 5, 1998, pp. 1-7.
(20) Niemeyer, S.C. and Spash, L. Environmental Valuation Analysis, Public Deliberation, and their Pragmatic Syntheses: A Critical Appraisal. *Environment and Planning C: Government and Policy*, Vol. 19, 2001, pp. 567-585.
(21) Banister, D. and Berechman, J. *Transport Investment and Economic Development*. UCL Press, London, 2000.
(22) Persky, J. Cost-Benefit Analysis and the Classical Creed. *Journal of Economic Perspectives*, Vol. 15, No. 4, 2001, pp. 199-208.
(23) Annema, J.A., Koopmans, C. and van Wee, B. Evaluating Transport Infrastructure Investments: The Dutch Experience with a Standardized Approach. *Transport Reviews*, Vol. 27, No. 2, 2007, pp. 125-150.
(24) Heinzerling, L. and Ackerman, F. Pricing the Priceless. Cost-Benefit Analysis of Environmental Protection. *University of Pennsylvania Law Review*, Vol. 150, 2001, pp. 1553-1584.
(25) van Wee, B. Rail Infrastructure: Challenges for Cost-Benefit Analysis and Other Ex Ante Evaluations. *Transportation Planning and Technology*, Vol. 30, No. 1, 2007, pp. 31-48.
(26) Ludwig, D., Brock, W.A. and Carpenter, S.R. Uncertainty in Discount Models and Environmental Accounting. *Ecology and Society*, Vol. 10, No. 2, 2005, pp. 13-27.
(27) Layard, R., and Glaister, S. *Cost-Benefit Analysis 2nd Edition*. Cambridge University Press, Cambridge, 2003.
(28) Skamris, M.K. and Flyvbjerg, B. Inaccuracy of Traffic Forecasts and Cost Estimates on Large Transport Projects. *Transport Policy*, Vol. 4, No. 3, 1997, pp. 141-146.

(29) Flyvbjerg, B., Bruzelius, N. and Rothengatter, W. *Megaprojects and Risk: an Anatomy of Ambition*. Cambridge University Press, Cambridge, 2003.
(30) Flyvbjerg, B. Policy and Planning for Large Infrastructure Projects: Problems, Causes, Cures. *Environment and Planning B: Planning and Design*, Vol. 34, No. 4, 2007, pp. 578-597.
(31) *Demand Forecasting Errors*. Transport Note No. TRN-12, World Bank, 2005a.
(32) Mayer, M.L.J. and McGoey-Smith, A.D. Risk-Based Cost and Schedule Estimation for Large Transportation Projects. Presented at European Transport Conference, Strasbourg, 2006.
(33) Salling, K.B. and Banister. D. Assessment of Large Transport Infrastructure Projects: The CBA-DK Model. *Transportation Research Part A*, Vol. 43, 2009, pp. 800-813.
(34) Rasouli, S. and Timmermans, H. Uncertainty in Travel Demand Forecasting Models: Literature Review and Research Agenda. *Transportation Letters: The International Journal of Transportation Research*, Vol. 4, 2012, pp. 55-73.
(35) Flyvbjerg, B., Skamris Holm, M.K. and Buhl, S.L. What Causes Cost Overrun in Transport Infrastructure Projects? *Transport Reviews*, Vol. 24, No. 1, 2004, pp. 3-18.
(36) Farber, D.A. and Hemmersbaugh, P.A. The Shadow of the Future: Discount Rates, Later Generations, and the Environment. *Vanderbilt Law Review*, Vol. 46, 1993, pp. 267-304.
(37) Weitzman, M.L. On the Environmental Discount Rate. *Journal of Environmental Economics and Management*, Vol. 36, 1994, pp. 201-208.
(38) Weitzman, M.L. Why the Far-Distant Future Should Be Discounted at Its Lowest Possible Rate. *Journal of Environmental Economics and Management*, Vol. 26, 1998, pp. 200-209.
(39) Weitzman, M.L. Gamma Discounting. *The American Economic Review*, Vol. 91, 2001, pp. 260-271.
(40) Florio, M. and Vignetti, S. Cost-Benefit Analysis of Infrastructure Projects in an Enlarged European Union: an Incentive-Oriented Approach. Presented at Fifth European Conference on Evaluation of The Structural Funds, Budapest, 2003.
(41) *Rail Project Appraisal Guidelines (RAILPAG)*. European Commission and European Investment Bank, 2005.
(42) Gerrod, G. and Willis, K.G. *Economic Valuation of the Environment, Methods and Case Studies*. Edward Elgar, Cheltenham, 1999.
(43) Miller, T.R. Variations between Countries in Values of Statistical Life. *Journal of Transport Economics and Policy*, Vol. 34, No. 2, 2000, pp. 169-188.
(44) Mrozek, J.R., and Taylor, L.O. What Determines the Value of Life? A Meta-Analysis. *Journal of Policy Analysis and Management*, Vol. 21, No. 2, 2002, pp. 253-270.
(45) Quinet, E. and Vickerman, R. *Principles of Transport Economics*. Edward Elgar Publishing, Cheltenham, 2004.
(46) De Blaeij, A., Florax, R. J.G.M., Rietveld, P. and Verhoef, E. The Value of a Statistical Life in Road Safety: A Meta-Analysis. *Accident Analysis & Prevention*, Vol. 35, No. 6, 2003, pp. 973-986.
(47) Trottenberg, P. and Rivkin, R. *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, 2011.

(48) Grant-Muller, S.M., Mackie, P., Nellthorpp, J. and Pearman, A. Economic Appraisal of European Transport Projects: the State-of-the-Art Revisited. *Transport Reviews: A Transnational Transdisciplinary Journal*, Vol. 21, No. 2, 2001, pp. 237-261.
(49) *Valuation of Accident Reduction*. Transport Note No. TRN-16. World Bank, 2005b.
(50) Rainey, D. *Value of Travel Time Savings*. Austroads, Haymarket NSW, 1997.
(51) Gwilliam, K.M. *The Value of Time in Economic Evaluation of Transport Projects: Lessons from Recent Research*. Infrastructure Notes, Transport Sector, Transport No. OT-5, World Bank, 1997.
(52) *Valuation of Time Savings*. Transport Note No. TRN-15. World Bank, 2005c.
(53) Rietveld, P. Infrastructure and Regional Development: A Survey of Multiregional Economic Models. *The Annals of Regional Science*, Vol. 23, 1989, pp. 255-274.
(54) Sieber, N. Spatial and Federal Transport Planning in Germany: How to Implement Spatial Planning Goals into Federal Transport Plans. Presented at 9th World Conference on Transport Research, Seoul, 2001.
(55) Vickerman, R. Cost-Benefit Analysis and Large-Scale Infrastructure Projects: State of the Art and Challenges. *Environment and Planning B: Planning and Design*, Vol. 34, 2007, pp. 598-610.
(56) Mairate, A. and Angelini, F. Cost-Benefit Analysis and EU Cohesion Policy. Presented at 5th Milan European Economy Workshop, Milan, 2006.
(57) Coto-Millan, P., Inglada, V. and Rey, B. Effects of Network Economies in High-Speed Rail: the Spanish Case. *Annals of Regional Science*, Vol. 41, 2007, pp. 911-925.
(58) Chintz, B. Contrasts in Agglomeration: New York and Pittsburgh. *American Economic Review, Papers and Proceedings*, Vol. 51, No. 2, 1961, pp. 279-289.
(59) Martinez, L.M. and Viegas, J.M. Effects of Transportation Accessibility on Residential Property Value. In *Transportation Research Record: Journal of the Transportation Research Board, No. 2115*, Transportation Research Board of the National Academies, Washington, D.C., 2009, pp. 127-137.
(60) Mera, K. Tradeoff between Aggregate Efficiency and Interregional Equity: A Static Analysis. *The Quarterly Journal of Economics*, Vol. 81, No. 4, 1967, pp. 658-674.
(61) Hewings, G.J.D. The Trade-Off between Aggregate National Efficiency and Interregional Equity: Some Recent Empirical Evidence. *Economic Geography*, Vol. 54, No. 3, 1978, pp. 254-263.
(62) Richardson, H. *Spatial Inequalities and Regional Development: Aggregate Efficiency and Intergenerational Equity*. Klewer, Dordrecht, 1979
(63) Masser, I., Sviden, O. and Wegener, M. Transport Planning for Equity and Sustainability. *Transportation Planning and Technology*, Vol. 17, 1993, pp. 319-330.
(64) Feitelson, E. Introducing Environmental Equity Dimensions into the Sustainable Transport Discourse: Issues and Pitfalls. *Transportation Research Part D*, Vol. 7, 2002, pp. 99-118.
(65) Thomopoulos, N., Grant-Muller, S. and Tight, M.R. Incorporating Equity Considerations in Transport Infrastructure Evaluation: Current Practice and a Proposed Methodology. *Evaluation and Program Planning*, Vol. 32, 2009, pp. 351-359.
(66) Shi, J. and Wu, Z. A Quantitative Transportation Project Investment Evaluation Approach with Both Equity and Efficiency Aspects. Presented at 12th WCTR, Lisbon, 2010.

(67) Martens, K. Substance Precedes Methodology: On Cost-Benefit Analysis and Equity. *Transportation*, Vol. 38, 2011, pp. 959-974.
(68) Wood, C., Dipper, B. and Jones, C. Auditing the Assessment of the Environmental Impacts of Planning Projects. *Journal of Environmental Planning and Management*, Vol. 43, No. 1, 2000, pp. 23-47.
(69) van Wee, B., van der Brink, R. and Nijland, H. Environmental Impacts of High-Speed Rail Links in Cost-Benefit Analyses: A Case Study of the Dutch Zuider Zee Line. *Transportation Research Part D*, Vol. 8, 2003, pp. 299-314.
(70) Laird, J.J., Nellthorp, J. and Mackie, P.J. Network Effects and Total Economic Impact in Transport Appraisal. *Transport Policy*, Vol. 12, No. 6, 2005, pp. 537-544.
(71) Chester, M., Horvath, A. *Environmental Life-cycle Assessment of Passenger Transportation: A Detailed Methodology for Energy, Greenhouse Gas, and Criteria Pollutant Inventories of Automobiles, Buses, Light Rail, Heavy Rail, and Air.* UC Berkeley Center for Future Urban Transport: A Volvo Center of Excellence, Institute of Transportation Studies, UC Berkeley, Berkeley http://escholarship.org/uc/item/5670921q#page-1. Accessed November 27, 2012.
(72) Lee Jr., D.B. Fundamentals of Life-Cycle Cost Analysis. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1812*, Transportation Research Board of the National Academies, Washington, D.C., 2002, pp. 203-210.
(73) *D12 – Service Concession Arrangements – Significance of Residual Value*. Agenda Paper 5(iii), International Accounting Standards Board, 2006.
(74) Edgerton, D. *Depreciation of Infrastructure Assets Technical Information Paper*. South Australia Local Government, 2002.
(75) Matria, T. 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, 2012.
(76) Odgaard, T., Kelly, C.E. & Laird, J. *Current Practice in Project Appraisal in Europe*. Deliverable 1 of the HEATCO project, European Commission 2006.
(77) Campos, J., de Rus, G. and Barron, I. *The Cost of Building and Operating a New High Speed Rail Line*. MPRA Paper 12396, University Library of Munich, Germany. http://mpra.ub.uni-muenchen.de/38676/. Accessed July 7, 2012.
(78) *ACT Lightrail Proposal to Infrastructure Australia*. Australian Capital Territory, Canberra, 2006.
(79) RITES India Ltd., and Silt Consultants Pvd. *Feasibility Study of Mechi-Mahakali and Pokhara-Kathmandu Electric Railway*. Government of Nepal, Ministry of Physical Planning and Works, Kathmandu, 2010.
(80) *Depreciation of Infrastructure Assets*. Technical Information Paper, South Australia Local Government (SALG), 2009.
(81) Woodward, P.D. Depreciation-The Development of an Accounting Concept. *The Accounting Review*, Vol. 31, No. 1, 1956, pp. 71-76.
(82) *High Speed Rail Study Phase 2 Report*. Department of Infrastructure and Transport, Australian Commonwealth Government, 2013.
(83) Casares, P. and Coto-Millan, P. Passenger transport planning. A Benefit-Cost Analysis of the High Speed Railway: The Case of Spain. *Atlantic Review of Economics*, Vol. 2, 2011, pp. 1-12.

(84) Rede Ferroviária de Alta Velocidade (RAVE). *Análise Custo-Benefício da Ligação em Alta Velocidade Ferroviária da Ligação Lisboa-Porto*. Steer Davies Gleave, London, 2009.
(85) Laurentiu, D. Determination of Residual Value within the Cost Benefit Analysis for the Projects Financed by the European Union. *The Annals of the University of Oradea*, Vol. 2, 2011, pp. 354-360.