Finance, Welfare and OEI: an Appraisal of Appraisals

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November 12, 2012

Abstract

Within financial economics, valuation is the practice of valuing entities – securities, projects, firms – generating cashflows that accrue to its owner(s). By contrast, public projects or entities, such as transport infrastructure, are evaluated based on public welfare accruing to society as a whole. The field of transport economics is in part concerned with valuing costs and benefits in lieu of cashflows. We find, however, that public cost-benefit analysis and private valuation share many methodological similarities in how these items are aggregated and adjusted for time and risk. In this paper, forays are made into private (financial) valuation and public appraisal of transport infrastructure projects, through study of both bodies of research. Subsequently, a survey is made of the standing practice of transport project appraisal by examination of the *OEI Leidraad*, which is then compared with best practices from both fields of theory. We conclude by identifying 'best practices' from both fields that may serve to improve accuracy of infrastructure appraisal in The Netherlands.

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Chapter 1 – Introduction

Proposals for major infrastructure projects are usually subjected to a thorough cost-benefit analysis by budgetary or regulatory bodies, in order to evaluate their impact on social welfare. A substantial body of literature exists on financial analysis of public works projects, a field usually seen as distinct from "conventional" investment analysis employed by corporations and investors. Academically, these disciplines are generally considered to form disjoint areas within the greater field of finance and economics.

There is an evident difference difference in methodologies and variables employed in public cost-benefit analysis, such as social (non-financial) costs and the estimation of higher-order ("knock-on") effects. Due to the sheer amount of often ill-defined variables that comprise both costs and benefits, these analyses are seen as subjective, error-prone and speculative, leading policymakers to make decisions that may imperil social welfare. Efforts have been made to improve this, for instance by drawing up common standards to which cost-benefit analyses must adhere. Nevertheless, a degree of ambiguity is likely to remain – if only due to the unique nature of each project's demands and context. Furthermore, the acuity of cost-benefit analyses can be disputed ex post: evidence has been found for persistent, structural cost overruns for an overwhelming majority of large infrastructure projects constructed around the developed world.

Financial economics, encompassing areas such as corporate finance, investment analysis and valuation, makes use of a comparatively limited and well-defined set of techniques. Extensive use by academics and corporate practicioners alike has given rise to time-honed and evidence-based frameworks, from the ubiquitous Net Present Value methodology to the increasingly popular Real Options theory. These methodologies form the backbone of financial project analysis in the private sector.

The Netherlands has seen extensive public discussion on the financial and social merits of large infrastructure projects. From the 1990s onward, extensive cost-benefit analyses have gained prominence in these discussions, precipitating the development of a framework (the *"OEI-leidraad"*) to be used for all major infrastructure projects undertaken by the central government. Several of such projects have been shelved or axed following a negative cost-benefit analysis; others have been called into question following their development.

In this paper, the main question addressed is, "To what extent is transport infrastructure appraisal from a public welfare perspective similar to private financial investment analysis?" This gives rise to a set of subquestions: "How are transport projects valued from a purely financial perspective?"; "What is the degree of overlap between the methodological underpinnings in both fields?"; "How do practices from both fields shape established appraisal practice in The Netherlands, and in what proportion?" and finally, "Would a greater convergence between financial and welfare economics serve to improve existing appraisal practices and benefit society as a whole?"

To this end, we shall attempt to identify common factors and conceptual differences between these "schools" of project evaluation. Literature from two disjoint subfields of economics will be studied, in addition to established policy in one country (The Netherlands). First, an attempt will be made to glean from the field of financial economics a set of methodologies that pertain to the context of public projects. Subsequently, a study is made of existing literature in the fields of transport economics and public finance, with the aim of identifiying common, evidence-supported factors used as inputs for cost-benefit analysis, specifically of infrastructure projects. A survey is made of impact analyses performed to measure indirect social and external costs and of financial variables (e.g. time horizon, (social) discount rates, cost of capital) used to measure direct costs.

Complementing a review of academic literature, an analysis of Dutch policy documents and previously published analyses is performed. With the guidelines set forth in the *"OEI leidraad"* – the prevalent regulatory framework for transport project appraisal – these will constitute a survey of the present state of affairs in The Netherlands with regard to infrastructure project evaluation. Finally, some recommendation are provided – based on the two literature studies – to improve transport infrastructure appraisal in The Netherlands.

Following this introduction, Chapter 2 will examine methods of appraising (transport) infrastructure from a financial point of view. Chapter 3 introduces the concept of "cost-benefit analysis", segueing into an exposé of the numerous "line items" of such analyses, borrowing heavily from transport economics literature. Following largely the same structure, Chapter 4 goes on to scrutinize the CBA practice in The Netherlands, highlighting a number of pivotal theoretical and methodological issues. Chapter 5 attempts to find common ground between the chapters that precede it, with the aim of improving transport project appraisal by addressing some of the theoretical deficiencies found before. Chapter 6 tallies the key differences of methodology found in the chapters theretofore and concludes.

Chapter 2 – Financial Economics

2.1 Introduction

Within the field of Financial Economics, valuation is an important discipline concerned with deriving a "fair" or "right" value for any asset, product or contract that produces a stream of payoffs contingent on time and risk. The subfield of Corporate Finance, in particular, is home to a variety of well-known techniques aimed at valuing securities (such as stocks and bonds) and investments (such as projects, prospects or entire companies) given their payoff structure, risk profile and the prevailing time value of money. By extension, these techniques may also be applied to (public) infrastructure projects – they are, in a sense, (physical) assets, acquired or commissioned at a specific price (e.g. construction cost) with a time-dependent payoff structure. In this section, we will investigate the potential use of selected valuation methodologies to appraise infrastructure projects.

In spite of their similarity to financial assets, infrastructure projects differ profoundly in one regard – the presence of indirect and external costs and benefits. Public infrastructure projects' expected viability is dependent on a host of "non-material" gains, such as increased speed and convenience of travel, higher-order benefits, e.g. job creation and increased "desirability" of a specific locale, and non-monetary costs like pollution and noise production. This is at odds with the norm prevalent in financial economics valuation to focus exclusively on cash flows, even leaving out any accruals, deferrals and non-monetary payoffs. Furthermore, public infrastructure is often "non-exclusive", in that even its purely monetary cost of use is not fully borne by its users but covered by general public spending or specific subsidies. Finally, all too frequent cost overruns (Flyvbjerg, Skamris Holm, & Buhl, 2003) and uncertain ridership or usage projections make viability estimation an inexact endeavour.

These considerations are likely to markedly affect a project's evaluation when performed ex ante. However, the directionality of this disparity may vary from one project to the next, depending on the proportion of immaterial costs and benefits taken into account. From a financial perspective, public infrastructure projects may thus be over- or undervalued compared to their "fundamental" cashflow value. A project generates benefits irrespective of ownership or funding structure, *ceteris paribus* – though the fashion in which these benefits constitute a "reward" in line with the principal (public or private) is different. Whereas a public entity (i.e. government) is content with the mere presence of such benefits, in line with its objective of maximising social welfare, only the portion of benefits that can be "captured" in pricing accrues to private parties. While there might be compelling reasons for constructing an infrastructure project that is not financially viable, a private party with a profit-maximising objective is not likely to do so, leaving it to the government to fund any shortfall.

Disparities aside, rising involvement of the private sector in infrastructure commissioning and operation has given rise to a body of research pertaining to the financial (as opposed to social) viability of projects. This research is generally set in a context where private funding is attracted or used under the aegis of a government, such as a BOT (build-operate-transfer) framework, a PPP (public-private partnership), foreign investment or outright privatization. Rather than being concerned with the nature of these frameworks, we are are interested the concomitant fashion of appraisal, in a sense evaluating projects as if they were owned privately. A large minority of research also introduces, and sometimes focuses on, the composition of capital structure in (partially) privatized infrastructure projects; we shall generally not make use of these analyses (barring cases were capital structure is not the single deciding factor, as in (Zhang, 2005)). In the next subsections, we shall cover a selection of findings deemed relevant to the subsequent analysis.

2.2 Discounted Cash Flow analysis

Discounted Cash Flow, or DCF, analysis represents the archetype of *intrinsic* valuation schemes – wherein an asset is valued without comparison to any other asset, comparable or not. As Damodaran (2002) described, *"In discounted cashflows valuation, the value of an asset is the present value of the expected cashflows on the asset, discounted back at a rate that reflects the riskiness of these cashflows."*. In short, the asset's "fair price" is comprised of the sum of its cashflows, transformed to account for time and risk. This method can be applied to a wide variety of financial and physical assets, such as securities (stocks and bonds), real estate, corporations, natural resources and investment projects. Its more general form, known as **Net Present Value** analysis, dispenses with the emphasis on "hard" cash flows and is hence applicable to *any* form of payoff – such as social utility.

In spite of this apparent rigidity of definition, it bears repetition that DCF analysis is usually applied to <u>future</u> cashflows, introducing a source of uncertainty into the calculation. Whereas some financial assets such as fixed-coupon bonds and residential mortgages have time-invariant (nominal) payoffs, most assets and projects require that a projection of future payoffs be made. Furthermore, depending on the expected holding period of the asset, or the duration of its cash flows (sometimes *ad infinitum*), estimation of a "terminal value" is required. As we will see in the next section, uncertainty of payoffs is a major contributor to the inaccuracy of infrastructure valuation.

Another subjective factor of note, and one that is rarely if ever certain, is the discount rate to be applied, to account for the decreasing value of payoffs as they take longer to materialize. Suggestions abound, such as the "risk-free rate" (for which there are numerous sources, and which tends to be determined nationally), the "cost of capital" of the investor, the expected rate of inflation or a composition of several factors, sometimes adjusted by including one or more "risk factors". Academic opinion on the merits of this "fudging" differ, with some preferring to adjust cashflows instead, while maintaining a theoretically defensible rate.

In practice, financial assets are usually valued using the Capital Asset Pricing Model to derive the discount rate. This model, commonly called 'CAPM' was devised in in 1964 by W.F. Sharpe, J. Lintner and J. Treynor, and *"states that under some simplifying assumptions, the rate of return on any asset may be expected to be equal to the rate of return on a riskless asset plus a premium that is proportional to the asset's risk relative to the market"* (Mun, 2006). In effect, as an investor can acquire a comprehensive range of alternative assets – with similar characteristics yet different sources of risk – he only needs to take the proportion of risk into account that cannot be 'diversified away', without being concerned with diversifiable risk. In short, all "ideosyncratic" risks are ignored for valuation purposes, and only market risk – the degree in which an asset's returns are related to those of "the market" – counts. To hold an asset, the investor needs to be compensated commensurately for the risk he thus takes on. Hence, a markup commensurate to the "market risk premium" is then added to the investor's cost of capital, as follows:

$$r = r_f + \beta(r_m - r_f)$$

Where r is the rate of return demanded, r_f represents the return on a risk-free asset and r_m represents the rate of return on the market (Brealey, Myers, & Allen, 2008). β measures the asset's sensitivity to market risk and is usually obtained through regression analysis.

This method presumes the existence of a range of similar assets and a market wherein these may be traded, unimpeded by prohibited transaction costs and the ability of an investor to acquire several assets concurrently. Needless to say, there are some financial assets and a great majority of physical assets to which these conditions do not apply (Mun (2006), Ye & Tiong (2000), among others). Garvin & Cheah (2004) make some effort to address this, by devising alternative methods of calculating the discount rate. In his critique of the Net Present Value method (2006), Mun outlines CAPM's flaws argues that different discount rates be used for costs and benefits (or profits), merited by supposed differences in risk. Several authors have advocated a multifactor extension to CAPM to account for factors not "captured" by the beta coefficient.

The CAPM method is often extended to include the principal's capital structure (the proportion in which debt and equity make up the funder's balance sheet) and its effect on taxation, stemming from the deductibility of interest payments. This leads us to the (after-tax) Weighted Average Cost of Capital method:

$$WACC = r_D(1 - T)\frac{D}{D + E} + r_E\frac{E}{D + E}$$

where WACC represents the discount rate to be used, r_D the cost of debt, T the marginal tax rate for the firm (relevant as interest payments are generally tax-deductible whereas returns to equity are not), D and E the amount of debt and equity, respectively, and r_E the cost of equity – which may be determined using CAPM. Mun provides an extension to WACC to account for the issue of preferred stocks; this addition is trivial and doesn't fundamentally alter the method's implications (2006). He goes on to label the use of the same CAPM-based discount rate as "disastrous", as it biases a firm towards risky projects, arguing for the use of an "internal beta" based on the firm's own portfolio of projects (rather than a market-based coefficient).

The quandaries described above illustrate that, in spite of its well-defined methodology, DCF analysis is still a largely subjective endeavour. As Rosenbaum & Pearl put it, it is only as strong as its assumptions (2009). In addition, there are factors that render DCF – or NPV – ill-suited for infrastructure project valuation. One is the absence of a liquid market for similar assets, and the impediment this poses to determining the appropriate discount factor to be used. Another is the nontrivial task of forecasting cash flows or payoffs – in effect, the estimated usage of the final product (Garvin & Cheah, 2004). Given the long construction times and even longer usage lifetimes commonly associated with infrastructure, the problem is exacerbated (Ye & Tiong, 2000). Finally, NPV analysis fails to account for managerial flexbility (Guthrie (2009), Mun (2006), Ping Ho & Liu (2003)), such as the possibility of delaying, expanding, contracting or abandoning the project in the face of changing conditions. As Mun stipulates, *"discounted cash flow is not necessarily wrong at all; it only implies zero uncertainty in the future forecast of cash flows"* (2006), going on to note that disregarding management's ability to make midcourse corrections leads to an undervaluation of projects. A similar notion is espoused by Guthrie, adding that this constitutes an irrational reluctance by managers to fully exploit their flexibility (2009).

2.3 Simulation-based methods

Given the great amount of uncertainty inherent in estimating and forecasting project cashflows, the "single-point estimate" produced by conventional valuation methods beget little confidence, as no information on its accuracy is conveyed (Mun, 2010). A step up is using sensitivity analysis, where changes to key variables are made *ad libitum* to gauge their effect on project value, or to use scenarios, which use allows several variables to change in accordance with (exogenous) project-specific factors deemed most relevant. Arguably, both methods are very popular in infrastructure appraisal, as we will see in later chapters. However, neither provides anything in the way of useful *statistical* information, such as probability distribution or even a sensible mean outcome. Monte Carlo simulation is the logical next step to address this deficiency; developed in the first half of the 20th century (when it was used in physics and nuclear weapons research) it was made greatly more feasible by the advent of personal computing. By running thousands of iterations of "sample paths", each with (slight) variations in inputs according to their respective distributional characteristics, it provides a hitherto impossible amount of information on the project's value distribution, such as the likelihood of it turning negative. Plus, it is the only method that explicitly allows intervariable correlations to be taken into account (Belli, 1996). Simulation complexity can be limited by including only those variables that have been found to exert the most influence on project value (Mun, 2006); conventional sensitivity analysis may be employed to this end.

2.3.1 Quantitative Risk Analysis

An application of Monte Carlo Simulation in project appraisal is provided in (Rode, Fischbeck, & Dean, 2001). Considering possible valuation approaches – net book value, replacement costs, comparable sales and income capitalization (NPV) – the authors judge that none are adequate for valuing industrial properties, least of all nuclear power plants. A variety of uncertainties – market, political, technical etcetera – and the large, "one-off" nature of such facilities require an income capitalization model that incorporates relevant risks. To this end, the authors use Quantitative Risk Analysis (QRA). It comprises a Monte Carlo simulation of two-step iterations: first, a multi-year sequence of "major" events (failure, nuclear fuel replacement, normal operation) is generated; second, a series of cashflows is simulated over a nineteen-year period to arrive at an NPV figure. In this way, the authors claim the possibility of taking "hundreds" of uncertain input parameters into account, whose values are drawn from its entire respective distribution. Using "hundreds of thousands" of iterations, this method produces a "cumulative distribution function" of project NPVs, yielding mean value, the likelihood of negative NPV as well as the range of outcomes.

2.3.2 Net-Present-Value-at-Risk

Citing deficiencies in the present valuation methods used for valuing Build-Operate-Transfer projects, such as payback period, NPV and IRR (Internal Rate of Return, covered in subsection 2.5), Ye & Tiong devise a new method, dubbed NPV-at-Risk (2000). As a rationale they mention the unusually long lead times and operating periods, as well as high capital outlays, for BOT infrastructure projects compared to other investments. These factors render risk analysis nontrivial using conventional methods, such as discount-rate adjustments. As an added impetus for the development of NPV-at-Risk the authors refer to the Asian financial crisis, in which numerous BOT projects across Asia had to be bailed out by governments.

Following a survey of sixteen existing, variegated valuation techniques, the authors conclude that no single one incorporates risk, provides a confidence level, and accounts for financing structure. NPV-at-Risk is then defined as comprised of a synthesis of Expected NPV (related to methodologies that lean heavily on statistics, such as mean-variance analysis) and Weighted Average Cost of Capital (WACC), as commonly used in corporate finance contexts. The Expected NPV portion reflects most of the risk, whereas WACC mainly accounts for capital structure (though WACC still "captures" some risk inherent in the project's cost of capital, the authors maintain NPV-at-Risk as a whole does not overstate risk). In short, NPV-at-Risk is then defined as the minimum expected NPV at a given confidence level. NPV-at-Risk however differs from Value-at-Risk in that it expresses the minimum project return at a given level, whereas Value-at-Risk describes the greatest loss one can expect within a predetermined time horizon (Mun, 2010). Also, NPV-at-Risk takes the time value of money into account.

The authors then demonstrate their methodology by using it to estimate two power plant projects with similar "base case" cashflows located in environments with differing risk profiles. This affects numerous project-relevant variables which, in turn, affects actual cashflow. Using Monte Carlo analysis, they generate each project's NPV distribution to show that only one of two projects is a viable investment. They conclude by showing investment decisions generated by the sixteen other methods surveyed, demonstrating the inability of most to capture all the risk factors inherent in the sample projects.

Ping Ho & Liu, however, cite criticism in (Myers, 1976) as a potential drawback to NPV-at-Risk, stating that it double-counts risk and results in an ambiguous distribution (2003).

2.4 Real Options

Following the inception of option theory within the realm of finance, option theory is gaining currency in a variety of other areas. Zhao & Tseng define *real options* as "the options embedded in operational processes, activities or investment opportunities that are not financial instruments" (2003). Real options valuation has been employed in a wide range of options, such as natural resources (Damodaran, 2002), drug research (ibid), market entry (ibid), gas storage (Thompson, Davison, & Rasmussen, 2008) , building expansion (Zhao & Tseng, 2003), optimal building heights (Titman, 2001) forestry (Guthrie, 2009), and industrial decommissioning (ibid).

Real options valuation offers some compelling benefits in infrastructure valuation that set it apart from other methods in the field of financial economics. As Damodaran writes, assets " that have the potential to create cash flows in the future but do not right now" are the most difficult to value (2002). Trigeorgis posits that management's flexibility to alter or delay decisions in the face of uncertainty and changing circumstances is impossible to properly capture using the NPV method (1996). Hull argues that such options "have quite different risk characteristics from the base project and require different discount rates" when appraised using the NPV method (1999). Garvin & Cheah note that 'traditional' valuation methods are best suited to engineering projects that result in cost reduction; when investments create future growth opportunities, for instance, in case of favourable demand, DCF methods understate the value of flexibility (2004). Copeland & Keenan point out DCF's origin - as a way of valuing securities – as the reason for its disregarding of managerial flexibility, stating that "DCF techniques…assume that companies hold investments passively" (1998). Furthermore, the asymmetric nature of an infrastructure project's payoffs cannot be modelled correctly using the NPV approach, being in nature more similar to financial options (Ping Ho & Liu, 2003).

This asymmetric nature is made possible by the oft-touted managerial flexibility being used to curtail losses when they arise.

Several "levels of distinction" exist within (real) option parlance. The first two were borrowed from the realm of financial options: call versus put and option "nationalities". *Call options*, originally, referred to options to *buy* the underlying asset at a predetermined price (the *strike price* or *exercise price*) before the maturity date – their value increases with that of the underlying asset, whereas *put options* provide an option to *sell* the underlying asset before maturity and hence increase in value as the asset's price drops below the strike price. These options may be bought and sold, giving rise to four different combinations and respective payoff structures. Option "nationality"derives not from any geographic specificity but solely from monikers given to groups of options with similar exercise rights. *European options* are exercisable only at maturity, whereas *American options* may be exercised at any time before maturity as well. *Bermudan options* are like American options, but may not be exercised during specific "blackout periods". A succinct overview of the differences between financial and real options is provided in (Mun, 2006)

Apart from the technical typology described above, real options are generally classified by *what type of optionality* they represent. Table 1, adapted from (Trigeorgis, 1995) and (Mun, 2006), provides an overview of the options thus distinguished. These may be combined in a variety of ways: for instance, a company may over time be able to either expand, contract or abandon production, based on changing market conditions (Mun, 2006); this situation is a *compound option* of expansion, contraction and abandonment options – this is also called a *chooser option*, in which the company has the option of choosing the best real option available at the time. Note that the "Option type" column is a generalisation, mainly with respect to nationality: due to their tailor-made nature, real options may also be modelled as European or Bermudan (depending on the exact nature of the optionality in question).

Category	Description	Option type	Examples
Deferment ("wait and see")	The owner of a resource waits to see whether prices (underlying value) change before deciding on exploitation.	American Call	Natural resource extraction (e.g. oil production), real estate development
Time to build (phased/staged investment)	Staging investments in a project in such a way that they can be abandoned "midstream", instead of in one go	Compound option (option on option)	Research and Development, large-scale construction
Expansion	Expand production, sales or operations in the face of conditions (price) changing favourably	American Call (or portfolio thereof)	Consumer goods, production facilities, venture capital
Contraction	Scale back production, sales or operations when conditions turn unfavourable	American Put (or portfolio thereof)	Consumer goods, production facilities
Abandonment	Terminate operations and sell assets for (known) salvage value when project is no longer profitable	American Put on dividend-paying asset	Capital-intensive projects: railroads, airlines, factories
Switching (outputs, inputs or processes)	Maintaining the possibility of changing production process during project lifetime	Call + Put Option or compound thereof (European or American)	**Input switch:** chemicals, power generation **Output switch:** batch production, factories, consumer goods, cars
Barrier	Option dependent on (price) reaching an artificial barrier	Call + Put option or portfolio thereof	Venture capital, asset acquisition

Table 1: Real Options by type. Adapted from Trigeorgis (1995) *and* Mun (2006)

A variety of methods have been developed to apply real options analysis in practice. Mun demonstrates 'lattice' method (2006), akin to the binomial tree approach devised in (Cox, Ross, & Rubinstein, 1979). Use of Monte Carlo simulation is another possibility (Hull, 1999), providing greater leeway in modelling multiple stochastic processes or variables. This method is computationally more intensive than the former (Zhao & Tseng, 2003). So-called "closed-form solutions", sets of equations made to befit a specific option type, may be used as well when such a solution exists. An example of this is the Black-Scholes formula: developed to price financial options, it may also be used to value real options, as shown in (Hull, 1999), (Mun, 2006) and (Damodaran, 2002). Another taxonomy, dividing real options models in discrete-time (e.g. lattice-based) and continuous-time (e.g. closed-form solutions) models, is used by (Garvin & Cheah, 2004) and (Cox, Ross, & Rubinstein, 1979). According to Mun, closed-form solutions, partial-differential equations and binomial lattices are used most widely (2006). Binomial lattices are favoured for their intuitive ease of use and flexibility – they are applicable to all types of options.

Compared to most other methods discussed in this section, applications of real options abound in the area of infrastructure finance. Garvin and Cheah analyse a toll road project using "base-case" NPV amended by a deferment option, finding significant value in the latter, illustrating a potential benefit of using both methods (2004). Zhao et al (2004) develop a detailed framework based, on real options, for highway construction and maintenance decisions; using multistage stochastic Monte Carlo analysis and least-squares regression, they find promising results in finding "optimal" decisions. Zhao and Tseng (2003) use the lattice method to gauge the economic value of providing for possible later expansion when constructing a parking garage (for instance, by building stronger columns than initially necessitated), concluding that "failure to account for flexibility is not economical". Likewise, Ford et al. use a simple real options approach devised by Kemna (1993) to compare 'basic' and 'flexible' design strategies when building a toll road, finding that the basic strategy undervalues the project's flexbility. Ping Ho and Liu (2002) introduce a model, based on the Black-Scholes formula, to address and value specific risks inherent in Build-Operate-Transfer projects. Building on their research, the authors develop an option-based model for technology research in the construction sector (2003). Rose (1998) pioneers a Monte Carlo simulation method to value "interacting" options embedded in a public-private toll-road project, with listed securities trading on the Australian market. He finds that the value of these options account for over half of the securities' value.

2.5 Internal Rate of Return

The notion of Internal Rate of Return (IRR) can be traced back to Boulding (1935), who stated that "the value of the enterprise at the end of the r^{th} year from its inception, V_r, is equal to the sum of the present values at that date of all future net revenues, discounted at the internal rate of interest", adding that every one object producing a revenue stream may be substituted for the enterprise as a whole. In other words, knowing the price of an asset, V, as well as its cash flow series x, we may solve the equation for i:

$$V_r = \frac{x_{r+1}}{(1+i)} + \frac{x_{r+2}}{(1+i)^2} + \cdots + \frac{x_n}{(1+i)^{n-r}}$$

The Internal Rate of Return is simply the discount rate at which a project's price is equated with its future cash flows. Or, when the project's acquisition, construction or investment price is included as a (negative) cash flow, "the interest rate that equates the present worth of a series of cash flows to zero" (Hartman & Schafrick, 2004). A project's calculated IRR may be used for investment decisions in two ways: compared to the company's cost of capital ("hurdle rate"), it must be greater in order to be viable, and compared to other IRRs for alternative projects (the highest is subsequently selected).

The IRR method has a number of well-known limitations. For one, a project may have several IRR values (above and below the hurdle rate), as mentioned – and addressed – by Hartman and Schafrick. Also, ranking projects by NPV and IRR sometimes produces different orders of preference (Osborne, 2010). Sometimes, there is no rate at all (Hazen, 2009). The latter two quandaries render IRR ill-suited to situations of uncertainty (ibid, Rothkopf (1965)), as it will be non-trivial to discover its distribution of values.

In spite of these well-known shortcomings, Internal Rate of Return is still widely employed in investment decisions. Remer, Stokdyk, & Van Driel (1993) discovered that 90% of surveyed Fortune 500 companies used it for corporate project evaluation in 1991. Osborne provides an overview of surveys, showing that IRR is still widely used by banks and large corporations. The IRR method is also used in an infrastructure and project finance context; Cuthbert & Cuthbert describe how the United Kingdom Treasury, while aware of the method's caveats, regularly uses IRR to evaluate "Private Finance Initiatives", a means for the private sector to finance public infrastructure projects (2012). In (Brown, 2005) "Real after-tax IRR" is revealed as the major trigger condition for payment deferral and concession termination in a selection of Australian PPP projects such as urban motorways.

Zhang develops a model for privatized infrastructure project evaluation, defining the objective as "maximizing the IRRE for the benefits of equity holders, while subjecting this objective to the requirements (formulated as constraints) of lenders and the government" (2005). To this end, a set of risk and financial (earnings and capital structure) indicators is drawn up, as well as a number of stylized formulas for combining them. For example, the "Ratio of Equity at Project Risks" is defined as the ratio of "risky" equity to total equity, which in itself forms part of the project capital (the remainder is debt). SFA, or "Self-Financing Ability", is defined as the ratio of discounted revenues to discounted construction costs, and proxies the project's ability to recoup its own cost of development. DSCR, or "Debt Service Coverage Ratio", is the quotient of the project's after-tax earnings and annual debt payments. Financial viability is expressed using IRRE, or "Internal Rate of Return to Equity".

To evaluate a project, Monte Carlo simulation is then performed – given certain distributional characteristics that vary by project – to determine project revenues, operating costs, and construction cost (including overruns). An iterative algorithm is used next, optimizing the project's financial viability with respect to equity ratio. Upon termination, the project is either deemed non-viable, or an optimal capital structure and IRRE are output.

2.6 Chapter conclusion

In the main, there appears to be little currency in financial economics for general infrastructure appraisal. Only when one specifies the context to include (partial) private financing – in PPP or BOT projects, for instance – does a relatively scant body of research emerge. We surmise that this paucity is related to the preeminence of transport and welfare economics in this practice area, and to the relatively general nature of most methods surveyed in this chapter: purely private infrastructure is, from a valuation perspective, not markedly different from other investment projects with a time-variant payoff and a degree of prediction uncertainty.

Perhaps, then, it stands to reason that infrastructure project valuation from a private financial-economic perspective uses largely the same "tools of the trade" as project evaluation in general. Income capitalization methods – those based on aggregating time-adjusted cashflows – reign supreme, as the large and unique nature of infrastructure projects render methods based on comparable transactions or replacement costs largely useless. As a result, DCF is widely employed, with its cousin IRR enjoying some popularity. Even the "revolutionary" real options method merely amends, not displaces, it: optionality value is calculated on top of basic, static project value – most likely the result of an NPV calculation. Similarly, simulation-based methods are a mere extension of the DCF principle to account for uncertainty and produce additional statistical info.

Table 2 provides a summary of the valuation methods found in this chapter and lists the relevant capabilities of each: Admissibility ("Does the method distinguish profitable from unprofitable projects?"), Preferability ("Can projects be ranked using this method?"), Risk ("Is risk attitude a parameter in the model?") and Flexibility ("Does it allow for, and value, decisionmaking at an intermediate stage?")

Method	Admissibility	Preferability	Risk	Flexibility
Discounted Cashflow (DCF)	Yes	Yes	Possibly[1]	No
Internal Rate of Return (IRR)	Yes	No	No	No
Real Options valuation	Yes[2]	Yes[2]	Yes	Yes
Simulation (e.g. QRA, NPVaR)	Yes[2]	Yes[2]	Yes	Possibly[3]
1 = through adjusting the discount rate 2 = assuming "base" method is NPV-based 3 = depending on nature of simulation (cf. QRA vs NPVaR)				

Table 2: Financial appraisal methods relevant to infrastructure projects

Chapter 3 – Transport Economics

3.1 Introduction

In the field of transport economics, infrastructure investment is generally esteemed in either of two possible ways: on a macro level, by means of its contribution to total economic output (such as GDP) or on a micro, or project level, where a project's gains are set against its costs. The former is usually achieved by tallying countrywide infrastructure investment and subsequently regressing it on output growth or level (macroeconometric analysis, a comprehensive review of which is provided in (Gramlich, 1994)); the latter is almost universally done by means of cost-benefit analysis. For purposes of comparability with the field of financial economics, covered in the previous section, this section will focus on the micro level. It bears consideration, though, that both methods are similar in one respect, in which they differ from financial valuation: on both levels, the impact infrastructure investment may have on the utility of society as a whole is appraised. In the end, the analysis is concerned with an engendered change in consumer and producer surplus (Vickerman (2007), Jorge & Rus (2004)). In other words, whereas valuation from a financial economics standpoint is solely concerned with monetary cash flows directly accruing to a project's owners (and therefore, "financial return" (European Commission, 1997)), these are but a subset of the wider costs and benefits that a valuator would aim to measure in accordance with established practices in the transport economics field. The array of costs and benefits thus gathered may be combined in a variety of ways to arrive at an investment decision. These in turn may require a number of additional inputs, such as discount rate, time horizon and probability distribution.

In this section we will cover relevant theoretical research on the subject of infrastructure project valuation, focusing on cost-benefit analysis. It is structured as follows: first, a general overview of the central tenets of cost-benefit analysis are covered; second, the myriad factors prevailing in *transport* policy appraisal are detailed. While some forays into policy guidelines will be made in connection to theory, section 4 will cover the current state of CBA practice in the EU and The Netherlands.

3.2 Cost-benefit analysis

Cost-benefit analysis is defined in (Rosen & Gayer, 2009) as "A set of procedures based on welfare economics for guiding public expenditure decisions", with the aim of "[enabling] policymakers to attempt to do what well-functioning markets do automatically – allocate resources to a project as long as the marginal social benefit exceeds the marginal social cost". Belli et al, using the term "economic analysis", summarize the practice as "[designing and selecting] projects that contribute to the welfare of a country" (Belli, Anderson, Barnum, Dixon, & Tan, 2001). It is chiefly employed to provide answers to two questions: first, given a project's cost and benefits, should the project be undertaken? (*admissibility*) Second, in the case of multiple admissible projects, which is to be preferred? (*preferability*) On this distinction, the European Commission *Guide to Cost-Benefit Analysis of Major Projects* declares that "Cost-Benefit Analysis is very much an exercise in detecting relative advantages of a project in comparison with other ones. Its main usefulness lies in that it makes possible a systematic comparison of different projects on the basis of common criteria for the measurement of costs and benefits. It is therefore not the absolute but the relative worth of a project that can be reliably estimated." (European Commission, 1997) For a (non-exhaustive) overview of CBA applications, the interested reader is referred to Browne & Ryan (2011). The history of the cost-benefit analysis practice is covered at length in Persky (2001). A context of Cost-Benefit Analysis in EU-wide transport appraisal is provided in Bristow & Nellthorp (2000). The manifold criticisms leveled at the CBA philosophy are succinctly reproduced by Annema et al (2006).

Before a policymaker may answer either of these questions, project costs and benefits need be estimated, surveyed, tallied or delimited and expressed in common units. Then, the aggregates of costs and benefits must be combined in a meaningful way, enabling a comparison to be made and, ultimately, an investment decision. Of prominence are three possible ways of performing this comparison: net present value (NPV), internal rate of return (IRR) and benefit cost ratio (Rosen & Gayer (2009), European Commission (1997)).

Net Present Value

As described in Section 2, NPV is a mainstay of valuation methodologies employed in the field of financial economics. Finding ample use in the valuing of securities, financial investments and entire enterprises, it may also be applied to project cost and benefits. Belli et al define it to this end as such:

$$NPV = \sum_{t=1}^{N} \frac{B_t - C_t}{(1+r)^t}$$

where N is the project's time horizon (in units of t), r represents the discount rate and B_t and C_t, respectively, the project's benefits and costs at time t. This definition is however at odds with (Rosen & Gayer, 2009), in which the project's initial cost (e.g. construction outlays) is subtracted from the sum of discounted net benefits. This subtraction is commonly understood to distinguish *net present value* from *present value*, the former being net of initial, e.g. construction or commissioning, cost. In this sense, the equation reproduced above represents a project's present value, or, in an extreme case, the net present value of a project with no initial outlays. In this case, any costs for construction, running or operating are included in the C_t parameter series.

It should be noted that largely the same set of advantages and disadvantages as outlined in Section 2 apply to the use of NPV in transport economics: the nontrivial decision on discount rate, the estimation of future costs and benefits and the impossibility of capturing certain aspects of flexibility. Nonetheless, these factors are also present or thought to outweigh those pertaining to other possible methods covered in this subsection; Rosen and Gayer deem NPV "the most reliable guide" (2009), Florio and Vignetti call it "one of the most crucial performance indicator [sic]" (2003).

Sometimes, several subtypes of NPV valuation are employed concurrently: the European Commission distinguishes *ENPV*, or *economic net present value*, and FNPV, or *financial net present value* (1997). The latter is calculated by discounting only financial cash flows using the project's financial discount rate. A negative FNPV may still result in project approval in the presence of significant socio-economic factors; rather, it provides the policymaker with an estimate of the amount of co-financing that is required. ENPV is derived from "vanilla" project NPV by correcting for price distortions and externalities; usually, any project with a negative ENPV when discounted at 5% is to be rejected, save in the presence of "substantial non-monetary net benefits".

Internal Rate of Return

Similar to NPV, Internal Rate of Return (IRR) is a method commonly seen in financial investment decision-making. It is defined in Rosen and Gayer as "the discount rate that would make the present value of the project just equal to zero". Similar to the use of NPV in valuing public projects, it is thus applied to the net value of benefits and costs for a specific period. Largely, the same disadvantages seen in IRR's financial use apply to its application in the public sector. Rosen and Gayer note another major shortcoming: when project sizes differ, IRR, as a relative measure gives poor guidance on which project contributes most to social welfare. In the public sector, this problem is compounded by the unique nature of projects: a smaller project, though of a higher IRR, can generally not be repeated several times to match the contribution of a larger, lower-IRR project.

Internal Rate of Return is therefore ill-suited to answer the question of *preferability*, as a difference in IRR across projects may have several causes, only one of which truly related to project preferability. When used with the aim of determining project *admissibility*, the question is raised which rate to use as the acceptable minimum. Among the possibilities are "market interest rate" (Belli, Anderson, Barnum, Dixon, & Tan, 2001), "social discount rate" (European Commission, 1997), an arbitrary minimum positive value, zero, or a benchmark for similar projects in the past (ibid). As with NPV, the European Commission defines two variants of IRR: FRR, the Financial Rate of Return, and ERR, the Economic Rate of Return.

Benefit-Cost Ratio

The benefit-cost ratio, or BCR, is defined as the quotient of aggregate project benefits and costs. Usually, both are first discounted at an identical rate over a given time horizon before the ratio is calculated. It stands to reason that a BCR exceeding one indicates project admissibility, as project benefits exceed costs. When comparing projects, the project with the highest BCR is preferable. In this case, a similar caveat as with Internal Rate of Return applies – BCR is a *relative* measure, and provides no indication of a project's absolute benefits, being of little use when project sizes differ greatly and projects are non-repeatable.

Another significant drawback of the BCR method is made apparent in Rosen and Gayer. Contrary to NPV and IRR, benefit-cost ratio considers benefits and costs separately, rather than their difference. As a result, the ratio is malleable simply by classifying costs as negative benefits. Not only is this imaginable in situations where the valuator is of fraudulous intent; sometimes, classifying a line item as a cost or a benefit may be non-trivial, depending on its nature. One project may therefore have several possible benefit-cost ratios depending on the discretion of the valuator. Hence, BCR is not to be used on its own, in the absence of project NPV or IRR calculation. Benefit-cost ratio has no current equivalent in financial economics.

3.3 Valuing Costs and Benefits

As soon as one abandons the notion of restricting valuation to project cash flows, much less to items readily explained in a monetary denominator (such as accounting accruals, who are not strictly part of "cash flow" but nonetheless of a financial nature), a wholly new quandary confronts the valuator: how to attach a monetary value to concepts as diverse and vague as time savings, pollution, the non-occurrence of accidents and other items regularly seen in cost-benefit analyses of transport projects? In this subsection, we will examine how these questions are addressed in transport economics literature.

3.3.1 Direct versus indirect costs and benefits

When aiming to identify all factors relevant in effecting a social welfare change, another divide becomes apparent: that separating direct and indirect costs and benefits. Commonly, the former is understood to encompass all first-order effects arising directly from the use of the infrastructure, whereas the latter results *through* it use, though to the same set of stakeholders (distinguishing it from externalities). Oftentimes, these will merely be redistributed "reverberations" of the first effect; care must therefore be taken to avoid double-counting (Annema, Koopmans, & Van Wee, 2007)

3.3.2 Charges versus costs

In the parlance of the field, "user charges", "direct charges" or simply "charges", refers to the price paid by the user for the use of a particular piece of infrastructure. The level of user charges varies per type of infrastructure, from non-tolled roads, having no charges at all, to fully privately operated mass transit (as in Japan), where all (direct) cost is borne by the user. User charges are the most direct component of project revenue, attributable unambiguously to user and project, and readily expressed in monetary terms. As discussed in Section 2, direct charges constitute the mainstay of a project's benefits when valued strictly from a financial economics point of view. As private operators, contrary to the public sector, are not concerned with the wider welfare of society, privately financed projects are likely to focus on a project's expected revenue from direct charging. Indeed, as Vickerman argues, *"the private-sector investor will not be interested in the wider benefits deriving from a project unless these can be captured in direct user pricing"* (2007). Arguably, this explains in large part why most research on private financing of infrastructure projects is concerned with projects where the "cost recovery ratio" (European Commission, 2008) is high, such as toll roads, airports and private parking. In fact, Vickerman cautions that a formal CBA might induce private operators to raise their charges, with the aim of capturing the additional social benefits thus revealed (2007).

In common cost-benefit analysis direct charges – if at all present – are generally lower in size than the full set of project benefits, the remainder consisting of subsidies and other indirect revenues as well as non-monetary and external benefits (covered in the remainder of this subsection). Charges are not directly included in the cost-benefit analysis, as that would lead to double-counting: charges represent users' willingness to pay to use a certain facility, presumably because the use thereof provides them with certain benefits (such as time savings or simply the possibility of travel); the charges levied on them therefore present a monetary value placed on these benefits. As a result, when benefits are included, charges should not be, as they "mirror" (a part of) these benefits. According to the European Commission, publicly operated infrastructure projects rarely recover their investment funds from user charges (1998). This is not to say that transport economics is not concerned with the level of these charges; a large body of research exist on the "desirable" level of user charges with respect to cost. The European Commission, according to the "user pays" principle (ibid), favours charges that reflect all infrastructure costs, include external and environmental impacts, terming this aggregate "marginal social cost". In doing so, a socially optimal amount of infrastructure is provisioned, maximizing consumer surplus and keeping negative externalities to a minimum. Pricing signals may also serve the converse aim of curbing congestion and pollution (European Commission, 1995). Vickerman points out the non-trivial nature of charging based on "marginal social benefits": benefits that are direct, yet non-monetary, such as time saved and reduced accident probability, are hard to capitalize in prices (2007). Also, when the infrastructure market is characterized by imperfect competition, (private) operators might be tempted to set their prices above marginal social cost, severing the link between benefits and charges, to the detrimental effects outlined in (European Commission, 2008). A more profound problem is posed in public-private partnerships: as both sectors have different levels of information perceptions of risk, they are given to divergent perceptions of actual project costs, having an effect on user charges (Vickerman, 2007).

Rus and Nombela highlight another difficulty in establishing direct user charges in high-speed rail operations (2007). Given the high initial fixed cost of providing capacity (i.e. rail construction), a significant wedge exists between marginal costs in the short and long run. Setting charges equal to marginal social cost might therefore lead to prices that are higher than the social optimum. When neglecting secondary benefits, very high ridership levels (exceeding actual usage figures over fourfold) are required to satisfy the positive-NPV requirement at the government-mandated discount rate. Projects may therefore already contribute to social welfare at lower demand rates than required when focusing on direct charges alone. In other words, without subsidy, infrastructure beneficial to society might never be built. Recognizing these difficulties, most if not all research advocates some degree of correlation between charges and marginal social cost and benefits.

3.3.3 Valuing Time

Another oft-seen factor in transport evaluation is that of travel time saved by prospective users of the project under consideration. Grant-Muller, Mackie, Nellthorp, & Pearman note how time savings constituted a factor of "major significance" in transport projects, even though initially (in the post-war decades) there was little theory on how to value them (2001). Vilain mentions that a survey by the European Investment Bank found time savings making up on average 80% of quantified benefits in transport projects (1996). The European Commission has mandated the estimation of time savings (expressed in monetary terms) in analysis of, among other, airport and highway projects (European Commission, 1997). Rus & Inglada reckon, *ex post*, that time savings account for 22.5% of benefits of the Madrid – Seville HSR route (1997), whereas Rus and Nombela go as far as stating that *"[t]here are no important user benefits beyond time savings from diverted traffic and the willingness to pay of new passengers*" for high-speed rail in Europe (2007).

Like most non-monetary benefits, there is no straightforward 'best practice' technique of estimating or valuing this time saving. There exists, however, a significant amount of research on the considerations involved. Research largely agrees that travel time is best valued by its opportunity cost, in other words, by the income forgone while travelling. It follows, then, that a meaningful distinction is required between work-related and leisure travel (Bristow & Nellthorp (2000), among others): travel time that deducts from a person's working hours may simply be valued at his wage (cost to the employee) or at wage plus any other employment-related cost (cost to the employer, (Belli, Anderson, Barnum, Dixon, & Tan, 2001)). This leads to substantial value-of-time differences between countries, as demonstrated by Bristow and Nellthorp (6.3€ – 23€ per hour in 1994). Naturally, VOT will also vary among income groups within a country (Grant-Muller, Mackie, Nellthorp, & Pearman, 2001) which will lead to a degree of modal self-selection (Bristow & Nellthorp, 2000).

With work-related travel time readily quantifiable, estimating time costs of leisure travel is nontrivial. The absence of a (proxy) market relegates the valuation process to the same techniques as discussed in the subsection on accident prevention: conducting surveys and establishing WTP in hypothetical situations. (Bristow & Nellthorp, 2000) outline in brief some caveats in employing revealed or stated preference methods to this end, such as the need for a large sample size and the hypothetical nature of paying for leisure travel time. In absence of direct estimates, one might employ simple rules to thumb to derive leisure VOT from work-related time value: it stands to reason that leisure-related travel time is valued lower, as the act of working is foregoing leisure in exchange for a wage, and no wage is paid for leisure itself. Consequently, it follows that the employee values – to a certain extent – working higher than leisure (Belli, Anderson, Barnum, Dixon, & Tan, 2001). Belli et al advocate valuing leisure travel time at 30% of hourly wage, in the absence of better estimates (ibid). Bristow & Nellthorp find values ranging from 2.4€ to 5.3€ per hour for 1994, noting that these are consistent with work-leisure VOT ratios of 10 to 42 per cent used by most countries for valuation (2000).

The work-leisure distinction aside, sound VOT estimation is hardly a trivial matter. A single estimate will for instance be compromised by evidence of VOT dependence on modality and trip purpose; Belli, Anderson, Barnum, Dixon, & Tan provide 'default values' for different trips, depending on purpose (business trip versus commuting, freight) and modality (car, public transport, and the like) (2001); Bristow and Nellthorp envision a 'split' of value-of-time calculation by as much as six indicators including mode and purpose among others (2000). Grant-Muller, Mackie, Nellthorp, & Pearman cite evidence from meta-analysis that waiting, walking and interchanging is valued significantly higher than in-vehicle travel time (2001); this is corroborated by (Belli, Anderson, Barnum, Dixon, & Tan, 2001). Plus, time saved for the traveller depends on his original or alternative mode of transportation; in the HSR context, this is likely to be either the car or the aeroplane, leading to very different VOT estimates (Rus & Nombela, 2007). Furthermore, cross-border comparisons are hampered by widely differing measurement regimes and definitions (ibid). Second, as precise as it may be, the estimate of time saved is but a prediction that is made *ex ante*, usually before ground is broken. How does the analyst "extrapolate" current VOT estimates into the future, for the lifetime of the project? (Belli, Anderson, Barnum, Dixon, & Tan, 2001) posit that, as a rule of thumb, work-time VOT can be expected to grow with income (GDP per capita), whereas non-work VOT may either rise or fall, due to countervailing developments in the labour market. Finally, time savings might ultimately disappoint due to increased congestion and induced demand related to the project's construction. (Kidokoro (2004), Browne & Ryan (2011) and Kuosmanen and Kortelainen (2006))

3.3.4 Valuing Employment

The European Commission mentions at length the necessity of employment effects estimation in CBA of transport projects, both during the completion of the project (e.g. construction work) and afterwards (European Commission, 1997 and 2008). Most research focuses on posterior long-term effects on employment effected by a project's completion. Such employment effects are often a key component to the estimated "(regional) development benefits" often noted as among the major immaterial benefits of large-scale transport projects. Bruinsma (1989) highlights several factors detracting from the solidity of such estimates: decreasing marginal benefits to infrastructure expansion, the required presence of growth potential even in the absence of such expansion, the ambiguous nature of "regional development" and the general difficulty of separating infrastructure's effects from general economic growth and other relevant effects, such as agglomeration.

Mackie & Preston reason that employment benefits may be a mere measure of scope: what may be an intraregional increase in employment may be a transfer when considered (supra)nationally, greatly complicating the appraisal of transnational transport projects (1998). Vickerman points out that transport projects, aiming to increase employment in an (underdeveloped) peripheral region, might actually serve to shift employment away from said region by making commuting to core areas more attractive (2007); Albalate & Bel provide evidence from Japan that confirms this conjecture (2010). Calthrop, De Borger, & Proost describe how, in theory, infrastructure construction might actually reduce overall employment, as the affected population will reduce work in favour of leisure when income rises (2010); Bruinsma considers the same effect resulting from increasing availability of export products (see 3.5.3). Furthermore, the European Commission (1997) repeatedly points out that additional employment is not only a benefit, but a cost to some, making the case for valuing only *additional* income generated as a benefit, adding that employment may in turn beget more employment, as well as additional negative externalities. In its guideline on transport charging (1998), the European Commission adds that, through redistributive effects, a different charging system for infrastructure affects labour costs, making further employment changes possible.

3.3.5 Valuing accident prevention

One benefit that is often attributed to infrastructure alterations or expansions is a change in the rate of traffic accidents. According to Bristow & Nellthorp, accidents are generally included in transport project appraisals in the European Union (2000). They discern three components of accident cost imposed on society: direct costs, such as damage to vehicles and property, costs to the economy due to lost production (as a result of incapacitation of individuals) and "human cost in terms of pain, grief and suffering". Arguably, the latter is the least trivial to value monetarily, touching upon a longstanding, profound issue in welfare economics: what is the monetary value of a human life? Belli, noting the intractability of valuing human life directly, outlines a method to assess the cost-effectiveness of a life-saving measure in terms of Healthy Years of Life Gained (HYLG) (Belli, 1996). Bristow and Nellthorp describe three methods to express human life in currency terms, somewhat akin to the techniques used for valuing environmental externalities (see subsection 3.5.1): output methods, estimating the impact in terms of lost production, Revealed Preference, based on insurance payments or court-awarded damages, and Stated Preference methods (2000). Grant-Muller et al. aver that, initially, calculation of lost output was the dominant appraisal method in Europe; subsequent introduction of Willingness-To-Pay methods led to a dramatic increase in imputed cost of human life (2001).

Both papers tally the cost of human fatalities per country in the European Union, revealing a wide discrepancy between Greece, Portugal and The Netherlands at the lower end, and Austria, Finland and Sweden at the upper end of the spectrum. Grant-Muller et al. note how Portugal and Sweden differ 48-fold when adjusted for inflation (2001). Differences in appraisal methodology are deemed to account for the mainstay of this discrepancy; with the remainder accounted for by variation in income, culturally determined risk attitude and disparate definitions employed.

Belli et al posit that the issues at play in accident prevention largely parallel those found in estimating the benefits of health projects, such as vaccination (Belli, Anderson, Barnum, Dixon, & Tan, 2001). An example of a vaccination program is provided. Examples of estimating the value accident prevention in infrastructure project appraisal are, inter alia, given for High-Speed Rail in Spain (Rus & Inglada, 1997) and the United States (Levinson et al, 1996) and for various modes of urban transport in Belgium (De Borger et al, 1997).

3.4 Estimating demand or usage

Forecasting traffic demand is paramount to any transport CBA, due to the highly speculative nature of the endeavour – most, if not all, project effects lie in the future and are variable, i.e. dependent on project usage (Belli, Anderson, Barnum, Dixon, & Tan, 2001). A proper estimation may therefore materially affect a project's costs and benefits, internal and external (Eijgenraam, Koopmans, Tang, & Verster, 2000), possibly even 'tipping the balance' leading to project appraisal or rejection.

Accurate demand projection is hampered by several factors: optimism by project sponsors or contractors (Flyvbjerg, Skamris Holm, & Buhl (2003), Mackie & Preston (1998), and Vickerman (2007)), possibly worsened by the presence of skewed incentives, the non-marginality of large projects (Vickerman, 2007), the difficulties associated with using elasticities (Belli, Anderson, Barnum, Dixon, & Tan (2001) and Goodwin et al (2004)) and the very fundamental problem of basing one's assumptions on the current reality, shaping perceptions of future demand, cost, origin-destination patterns, modality preferences and technological possibilities (Vickerman (2007), Browne & Ryan (2011)). Indeed, any project whose benefits are estimated somehow in relation to current traffic levels is afflicted by this issue; as Vickerman puts it, *"projects which may* *take ten years to approve and a similar period to construct are faced with the clear problem that the assumptions built into any demand forecast are likely to have been wrong"* (2007). Even current usage levels may be non-trivial to esteem, given how traffic volumes exhibit significant variance over any considerable time span, rendering annualised data useless (Mackie & Preston, 1998). Another effect that is often neglected by planners is the "takeoff curve" exhibited by demand for a particular infrastructure facility. It stands to reason that no particular project will be fully used immediately upon completion, rather, traffic is expected to build up over time. The usual practice of discounting future benefits serves to aggravate the disparity when time-variant demand is taken into account (Mackie & Preston (1998), also, Canning and Bennathan (2000)).

Belli et al offer some guidelines in (Belli, Anderson, Barnum, Dixon, & Tan, 2001) for estimating traffic levels, distinguishing three types of demand: normal, or baseload traffic; generated traffic and diverted traffic. Normal traffic "would have normally occurred even in the absence of the project", generated traffic stems from "induced demand" (see section 3.5.2) and diverted traffic is existing traffic that switches to the new infrastructure facility (see also (Mackie & Preston, 1998)). Normal traffic may simply be estimated by extrapolation of the trend currently exhibited, or as resulting from changes in GDP (income), population or fuel prices. This, however, entails the use of a proper method to estimate these variables, as well as the use of elasticities of demand with respect to these variables. As Goodwin et al have shown, elasticities are time-variant, reintroducing in another way the problem of the "takeoff curve" described above. Additionally, these elasticities will likely differ among modalities, freight or passenger traffic, and purpose (leisure or work), as described elsewhere in this chapter. As for generated traffic, it too is commonly projected using demand functions ((Belli, Anderson, Barnum, Dixon, & Tan, 2001), (Vickerman, 2007)) and hence subject to the same quandaries of prediction. Belli et al advise that the valuator focus on traffic generated specifically by lower transport costs as a result of the project. Finally, the presence of diverted traffic, while constituting a transfer of benefits to society (rather than an improvement), needs to be considered so as to avoid double-counting of benefits to users.

As we will see in the next section, demand estimation constitutes a separate section of the CBA according to standing guidelines in The Netherlands. Often, this is achieved through a behavioural model, requisitioned from a separate (private) party.

3.5 Externalities and Environmental Considerations

Externalities are commonly understood to be costs or benefits, accruing from a transaction, to individuals or groups not party (i.e. buyer or seller) to said transaction. As (Belli, Anderson, Barnum, Dixon, & Tan, 2001) phrases it, *"A project may have a negative or positive impact on specific groups in society without the project entity incurring a corresponding monetary cost or enjoying a monetary benefit."* These effects are real costs and benefits and should therefore be included in the Cost-Benefit analysis of the project creating them. While this stands to reason, conventional CBA often fails in this regard (Belli, (Mackie & Preston, 1998)). When considering transport project, environmental externalities, such as pollution and noise, readily spring to mind. In the two decades past, an increasing amount of research has been conducted within the field of transport economics on evaluating environmental impacts and incorporating them into project appraisal. Furthermore, guidelines on environmental impact analysis have been laid down by regulators ((European Commission, 1995), CPB Leidraad). As Belli et al note, *"the presence of externalities has been one of the major sources of divergence between private and social benefits of projects"* ((Belli, Anderson, Barnum, Dixon, & Tan, 2001)). In this subsection, we will discuss the most relevant issues relating to external effects, covering environmental impact, network effects and miscellaneous "higher-order" externalities.

3.5.1 Environmental considerations

As Belli writes, the need to incorporate environmental externalities in cost-benefit analysis has been recognized from the outset (1996). Atkinson and Mourato phrase it thus: *"Within the context of CBA, the objective is to generate original (or primary) data on the total economic value that the public places on environmental changes that arise as a result of some policy proposal."* (2008) Given the nontrivial task of estimating these externalities, it took until approximately 1980 to devise a way to do so properly (Belli, 1996). Environmental externalities are commonly understood to comprise the effects a certain project has on the (natural) environment – pollution and noise being prime examples of environmental externalities often seen in the analysis of transportation projects. It should be noted that projects can also affect the environment positively, leading to an environmental gain. (Belli, Anderson, Barnum, Dixon, & Tan, 2001) provide an example of a sewer project: whilst the stated aim is to increase water quality and sanitation, it might lead to cleaner coastal water in time, which in turn increases beach visits and property values. Similarly, the construction of a high-speed train line is often justified by the "intermodal substitution" it will bring about, shifting traffic away from comparatively harmful transport modes such as aeroplanes and (personal) cars (Coto-Millán, Inglada, & Casares (2011), Albalate & Bel, (2010)).

Following identification of a project's environmental impacts, they must be valued by the analyst. Broadly speaking, the means by which to achieve this are split among two categories (European Commission, 1995): *stated preferences* (Kuosmanen & Kortelainen (2006), Atkinson & Mourato (2008)), similar to Belli's *contingent valuation* (1996) and *revealed preferences,* or *objective and subjective measurements* in the parlance of Belli. In the former, field studies, surveys or controlled experiments are conducted to estimate the impact on a certain aspect of the environment by constructing a hypothetical market for the presence of said aspect and gauging stakeholders' Willingness To Pay for its presence. The latter aims to achieve the same by scrutinizing stakeholders' behaviour in an *alternative market*, whereby a monetary value may be discerned from economic behaviour. Examples of revealed preferences are the differences in house prices in areas with varying air quality, providing a proxy for the value of air pollution (Belli, 1996), called *implicit* or *hedonic pricing*, and the *travel cost* method described in Atkinson and Mourato, where a nature reserve is valued by measuring the public's willingness to travel to it, thus expending fuel and time, among others (2008).

Both methodologies are rife with inexactitude and potential for flawed application: bias is often suspected in the stating of preferences (Atkinson & Mourato, 2008), and preferences for non-use (for instance, the existence of an endangered species) cannot be revealed when there is no alternative market (Kuosmanen & Kortelainen, 2006). Furthermore, the identification of environmental impacts *per se* is fraught with numerous issues. For one, is the duration of the impact commensurate with the project's lifetime (Belli, Anderson, Barnum, Dixon, & Tan, 2001) or is there a mismatch? When allocating funds to alleviate adverse impacts in the future, will they actually be used to this end (Atkinson & Mourato, 2008)? How are long-lasting environmental externalities to be discounted to the present? (Almansa Sáez & Calatrava Requena, 2007)

In spite of these quandaries, most unresolved as of yet, there appears to be general agreement in the field of transport economics that environmental externalities, flawed as their estimates may be, are best incorporated in cost-benefit analysis rather than left out altogether. For one, the very nature of cost-benefit analysis ties in with the original notion of Hicks and Kaldor, stating that a policy or project must be adopted when its full benefits exceed its full costs, so that (hypothetically) its gainers might compensate those that stand to lose from its implementation (Atkinson & Mourato, 2008). To abstain from incorporating the full cost of a project is to disregard the basic premise on which CBA is based. Another theoretical impetus for including environmental cost is that, ultimately, the project's price, charge or total cost will lead to the provisioning of a socially optimal amount (size of a project, volume of production, etcetera) of the project, at which net adverse effects are minimized (European Commission, 1995).

3.5.2 Network effects and induced demand

While Cost-Benefit Analysis ideally captures any and all costs and benefits that a given project bestows on society, the pictures becomes muddled when we consider effects that transcend the project and its users. For instance, road and rail projects may have significant network benefits (Mackie and Preston (1998), Laird, Nellthorp, & Mackie (2005), Kidokoro (2004), and Vickerman, (2007)). Laird et al define network effects as *"the second round reverberations on costs and prices in related markets as a result of a transport improvement"*, describing how investment in a part of the network potentially lowers unit costs for transport elsewhere (such as an additional train line that acts as a feeder for an existing route, increasing ridership). Network effects may just as well be costs, however – Laird et al list congestion as an example where an increase in traffic from other routes affects travel time across the network; Belli, Anderson, Barnum, Dixon, & Tan separate new routes into alternative links (lowering congestion) and complementary links or feeders, increasing congestion (2001). Induced demand, a familiar notion in transport economics, may in extreme cases result in a congestion *increase* following the commissioning of a new transport infrastructure project (Vickerman, 2007). Such network effects are generally overlooked in classic cost-benefit analysis (Laird, Nellthorp, & Mackie (2005), Kidokoro (2004), Calthrop, De Borger, & Proost (2010)) yet capturing them is increasingly tractable using general-equilibrium models (ibid). Vickerman cautions, however, that network effects vary from project to project and should therefore always be considered on a case-by-case basis, lest they be used to "augment" a project's benefits (2007). Another example of network effects is a "modal shift" engendered by the construction of a new project: when considering a nation's (passenger) infrastructure as a single network across all modalities, construction of a new connection will have network effects on the other modes as well. Coto-Millán, Inglada, & Casares provide, by demonstrating the effect of a newly-built HSR route on conventional rail, aeroplane and highway demand, a comprehensive example of such a network effect (2011). In a similar context, Rus & Inglada list decreasing highway congestion among the benefits of high-speed rail construction, along with other costs associated with car use (1997).

3.5.3 Price level effects

Further higher-order effects may result when the commissioning of an infrastructure facility lowers transport costs, affecting general cost and price levels. This, in turn, may effect national or regional competitiveness and trade flows. The European Commission estimates transport costs to account for 2.8% of final product prices in the EU, or 1-4% of sales value for most industrial branches, depending on distance, weight, modality and value-added (leading to a 6-7% peak for cement), noting that transport infrastructure improvements is unlikely to markedly affect product prices. However, transport **pricing** is likely to "significantly strengthen" European industrial competitiveness by eliminating congestion and accidents (European Commission, 1995).

Bruinsma describes how such "spin-off effects" take place in the long run (rendering them less significant as a result of discounting) and may sometimes be negative, a notion not considered in the EC report. For example, a drop in transport costs for certain modalities may make imports more competitive as well, driving local industries out of business. A theoretical model incorporating transport costs as input prices is developed in (Calthrop, De Borger, & Proost, 2010), such benefits are highly dependent on project nature, requiring a "bespoke" application in order to be meaningful in a CBA context.

3.5.4 Other higher-order effects

Apart from network externalities and environmental costs, other higher-order effects are sometimes included in cost-benefit analyses, such as economic activity, real estate price increases, and increased employment. Vickerman (2007) and Mackie & Preston (1998) advise that the valuator be wary of double-counting, as in perfectly competitive markets these effects will already have been priced in as downstream manifestations of the project's primary impact (arguably, the same might apply to several of the effects described in this chapter). Furthermore, such effects are nontrivial to allocate to a specific project for purposes of preferability, as a similar investment elsewhere might have a comparable effect. Some higher-order interaction may not be ruled out entirely, though; as Vickerman claims, *"Most economic analysis is based on the idea of marginal changes which can then be evaluated. Very-large-scale transport projects are clearly not marginal and the ceteris paribus assumption will not hold. The problem here is that the project itself changes those things which are expected to stay constant in order to enable the evaluation to take place."* (2007)

3.6 Discount rate considerations

As a corollary to the discount rate described in Section 2, discounting in transport economics follows a similar rationale of adjusting future payments according to their coming due over time. Atkinson and Mourato describe the practice in a CBA context thus: *"discounting involves attaching a lower weight to a given unit [...] of future benefit (or cost) than to an equivalent present unit"* (2008). A lengthier definition of discounting's conceptual underpinnings in the CBA context is given in (Belli, Anderson, Barnum, Dixon, & Tan, 2001). Generally, the discount rate employed in cost-benefit analysis is termed "social" discount rate, reflecting its encompassing of the wider impact on society (Florio, 2006). In this context, the "narrow" definition of discount rate, applying exclusively to cashflows, is dubbed "financial discount rate" (European Commission, 1995, among others)

Having mentioned conceptual similarities, a number of differences is readily apparent: for one, while in its "conventional" valuation definition, discounting is used to arrived at the net present value of a stream of **cashflows**, social discounting applies a discount rate to the aggregates of **all** costs and benefits, including non-monetary "payments" that might be appraised in a common denominator (e.g. currency equivalent) first. As discussed elsewhere in this section, this is one of the crucial conundrums in cost-benefit analysis; furthermore, it raises the question to what extent a single discount rate applies to such a "lumpy" aggregate consisting of items so diverse in type and identification. Additionally, while the underlying rationale is similar, the respective rates (financial or social) are seen as being determined by wholly different factors: the financial discount rate is predominantly driven by a combination of the (opportunity) cost of capital, i.e. the risk-free rate, and risk, for instance through an application of the CAPM model. As for the social discount rate, there is little scientific consensus on its correct determination (Almansa Saez and Calatrava Requena provide a lengthy history of the relevant discourse in (2007)). In this subsection, we will briefly cover some of the salient, competing views on establishing a proper social discount rate for infrastructure project valuation.

In a social context, the presence of discounting reflects an implicit attitude on intergenerational welfare. Central to the wider principle of present value is a diminishing preference for payments (whether financial or welfare-related) in the future; specific to social discounting over certain time horizons is that these future payments might be enjoyed or suffered by different people, possibly not even born at the moment of investment or analysis. Poignantly put by Atkinson and Mourato, *"[discounting] means that future generations'* *preferences count less than our own present ones"*. This quandary is especially prevalent when it comes to environmental issues, which have the potential to afflict humanity for very long, possibly unknown horizons (Atkinson & Mourato (2008), Kuosmanen & Kortelainen (2006)). At one extreme end of the debate, a discount rate of zero or less is advocated, for instance by Ciriacy-Wantrup (1942) and Shue (1999). The notion of sustainability as "allowing future generations to live as well as we do" (Solow, 1991) contradicts this attack on intergenerational discounting, provided that future generations may substitute other forms of capital to compensate for a declining stock of "environmental capital" (Almansa Sáez & Calatrava Requena, 2007) This notion in itself is debated, for instance in (Simón Fernández, 1995). The (inadvertent) disappearance of long-term environmental problems, such as climate change, by use of discounting is used by Atkinson & Mourato (2008) to argue for a discount rate that declines with time, and thus attributes comparably greater weight to future costs and benefits. This rationale is not strictly environmental in origin, also touching upon unknown future changes in preferences, interest rates, and the general economic condition (ibid).

This extensive body of discourse in literature aside, a more pragmatic view is advocated by some, and most often used in practice. An "off-the-shelf" proxy figure may be used, or a "yardstick" figure might be employed by regulators. Apart from the obvious benefit of absolving the appraiser of the profound, philosophical burden of formulating views on intergenerational equity, it carries the benefit of allowing all projects to be judged by the same benchmark (European Commission (1997) and Saerbeck (1990)). Commonly used "proxy" figures include the yields on a country's long-term government debt (preferably with a maturity that matches the project's time horizon) (Florio (2006), among others), European Investment Bank bonds (ibid), the marginal savings rate of its inhabitants (Belli, Anderson, Barnum, Dixon, & Tan, 2001), opportunity cost of capital (European Commission, 1997) and public expenditure growth (Florio, 2006). In practice, "benchmark" rates are often imposed by governments, with little thought given to theoretical soundness: (Bristow & Nellthorp, 2000) find that such rates range between 3% and 8% depending on country, whereas the European Commission usually mandates a 5% real rate to be used (Florio (2006), Rus & Nombela (2007), European Commission (1997)), and 7% in the United States of America. While this "imposition" of a social discount rate carries obvious benefits, it has little bearing on underlying factors that may differ widely across constituent states and funders, with bond yields, inflation and savings rates differing by up to 10 percentage points at times (Vickerman). Nevertheless, 5% is found to be the European average for state-mandated discount rates (Florio & Vignetti, 2003).

3.7 Time horizon considerations

Like discount rate, the choice of a time horizon for a project's CBA may have a meaningful impact on the project's esteemed benefits and costs, possibly even affecting investment decision (Browne & Ryan, 2011). A distinction should be made between the "lifetime" of the project itself (*project life*), the presumed depreciation period of its asset (*technical life*) and the duration of the cost and benefit streams included in the analysis, for these may differ (Belli, Anderson, Barnum, Dixon, & Tan (2001), Mackie & Preston (1998)). For instance, the nuclear waste generated by an atomic power plant will require secure storage for centuries, much longer than the power plant's actual operation, a highway project may generate higher-order benefits (such as employment) as well as costs (acid rain finding its way into the ecosystem) outlasting its analysis horizon, an education project requiring personnel will lead to a pension obligation to be fulfilled by the funder or the state. Mackie and Preston caution that, while a higher discount rate reduces the impact of a longer time horizon (costs and benefits in the future are greatly reduced by compounded discounting), the converse is not true: when a project's lifetime is inadvertently shortened to fall below the original CBA horizon, its effect on social welfare can change drastically (1998). To this end, the European Commission stipulates that the analysis horizon should not be longer than "the economically useful life of the project", overriding its own guidelines for infrastructure time horizons (European Commission, 2008). Any remaining cost/benefit streams should be aggregated into a "terminal value", akin to that used commonly in financial economics. The average time horizon for European transport projects was found to be 26.6 years (European Commission, 1997); the commission's guidelines advocate 25 years for road projects, 30 for railways, based on "internationally accepted practices" (European Commission, 2008).

3.8 Cost overruns

The 2003 paper by Flyvbjerg, Skamris Holm, & Buhl sought to compare costs and benefits forecasts for transport projects with costs and benefits actually incurred after project realization, claiming to be the first large-N study to do so. Examining 258 projects over an 81-year timespan across twenty nations, the authors find cost escalation to be pervasive across countries and persistent over time, affecting roughly 90% of projects surveyed. In other words, project appraisers have either failed to draw lessons from eight decades of CBA experience, or have learned that underestimating costs respective to benefits pays off. In a follow-up study (Flyvbjerg, Skamris Holm, & Buhl, 2004), the authors examined possible causes for this surprising lack of improvement, examining to what extent cost escalation is related to implementation phase length, project size (expressed in construction cost) and type of ownership – public or private. They find a strong relationship between implementation timespan and cost overruns, with costs increasing by 4.64% for every year added to the implementation phase. The relationship between project size and cost escalation is significant only for tunnels and bridges, and positive. Finally, on the type of ownership affecting escalation, the authors find a significant effect of a surprising nature: while projects owned by state-owned enterprises fare worst in terms of escalation, with an average overrun of 110%, private projects in fact perform worse than "other public projects" (such as those owned by government ministries), achieving 34% and 23% overrun, respectively.

In spite of its apparent persistence, the notion of averting, predicting or incorporating a measured degree of overrun is all but absent from the majority of CBA-related literature consulted. (Albalate & Bel, 2010) mention its presence in HSR projects, and recommend a certain degree of "fudging" be employed to temper expectations. The European Commission, in its 2008 policy document (European Commission, 2008) recognize the possibility of cost escalation (citing Flyvbjerg, Skamris Holm, & Buhl (2003)), mandating its inclusion in risk assessment studies, though abstaining from providing exact guidelines. Vickerman, finally, notes that the CBA debates focuses disproportionally on exact estimation of benefits, while costs (and potential escalation) merit closer examination (2007).

3.9 Probability considerations

Conducting a cost-benefit analysis requires the valuator to requisition a multitude of variables, some of which nontrivial to estimate properly (as amply demonstrated in the above subsections). It stands to reason, therefore, that the uncertainty inherent in establishing these values carry through into the analysis, preferably in an explicit form. In other words, the mere act of making assumptions to determine reasonable values for the relevant variables is a fundamental source of uncertainty (Atkinson & Mourato (2008) and Belli, Anderson, Barnum, Dixon, & Tan (2001)); if possible, the valuator should strive to make this explicit by applying some of the techniques known for this purpose. At the very least, expected value may be used when variables can take on multiple values; this, however, assumes risk neutrality on the part of the decisionmaker (Atkinson & Mourato, 2008). This risk-neutral stance, often assumed by the valuator, is deemed non-evident by the European Commission, when good reasons are provided for a different risk attitude. Often, one step further is taken and a sensitivity analysis is drawn up – defined by Belli et al. as *"[estimating] how sensitive project outcomes are to changes in the values of critical variables."* (Belli, Anderson, Barnum, Dixon, & Tan, 2001). This definition is amended by the European Commission, stating that any variable "for which 1% change results in a 1% change or more of ENPV or ERR is certainly a critical one" and should therefore be included in a sensitivity analysis. In its 2008 document, a sensitivity analysis is confirmed as mandatory by EU regulations. A special case of sensitivity analysis is called "switching analysis", and entails the identification of values for certain sets or ranges of crucial variables that render the project NPV-negative (Belli, Anderson, Barnum, Dixon, & Tan, 2001). A switching analysis may also be conducted ceteris paribus, showing the minimum necessary change in **one** of the crucial variables required to render the project unfeasible given average or "base case" values for all the others (as demonstrated in European Commission (2008)).

While there is arguable merit in these techniques, constituting a "step up" from the mere base case or expected value scenarios, Belli et al. identify two main drawbacks: neither probabilities nor correlations are taken into account (1996). The former is corroborated by the European Commission, which states that *"the practice of varying the values of the critical variables by arbitrary percentages does not have any relation with the likely variability* *of such variables"* (2008). In other words, while we know **to what extent** a variable affects the NPV, the analysis gives us no tools to infer the likelihood of such occurring. In addition, the "ceteris paribus" assumption underpinning switching analysis – and implicitly, sensitivity analysis as well – will most certainly not hold in reality (Belli, Anderson, Barnum, Dixon, & Tan, 2001). Changes in variables are often interrelated; for instance, GDP level affects travel time preferences (European Commission, 2008). Both are likely candidates for "critical variables" in a cost-benefit analysis for a large transport project. As a result, the valuator should strive to model these correlations and explicitly take interdependencies into account in the risk analysis.

The Monte Carlo method constitutes a powerful remedy for said shortcomings (Belli, Anderson, Barnum, Dixon, & Tan (2001), European Commission (1997), European Commission (2008)). By explicitly including distributions for each critical variable, allowing for the inclusion of delays and intervariable correlations, the project's **NPV distribution** is calculated, allowing for an unprecedented insight into the project's main drivers. Also, as a significant "side benefit", the most important variables are identified. Naturally, this requires that distributions for each variable be identified; this is likely to be a non-trivial endeavour in itself. At any rate, the dramatic increase in computing speed witnessed in the past put Monte Carlo simulation within reach of most, if not all, project evaluators. Perhaps surprisingly, Monte Carlo simulation is not included – or glossed over at best – in the majority of studies consulted for this paper, nor is its use mandated by the European Commission (it is merely "suggested" in European Commission (2008)). The theoretical and practical issues pertaining to Monte Carlo simulation will be revisited as appropriate later in this paper.

3.10 Chapter conclusion

Having reviewed an extensive body of theory on the subject of public infrastructure appraisal, it is revealed that, notwithstanding a great chasm of "investment philosophies", the mainstay of valuation methodologies proffered befit largely the frameworks established in financial economics, as covered in the chapter prior: the net present value method and its corollary, internal rate of return. Barring those that advocate general-equilibrium models or "macroeconomic surplus", most authors accept the general tenets of discounting a stream of future, uncertain "value flows" using a certain, non-zero time value of money. However, there is a stark difference as to the nature and origin of "value" and discounting. For one, the notion of "cash flow" disappears completely, relegated to a minor role in the form of "charges" as a monetary instantiation of benefits; these charges are – depending on methodology – not even a distinct component of value, but rather constitute its "mirror image" which partially overlaps perceived user benefits in line with the user's willingness-to-pay. As cashflows give way to balances of concomitant benefits and costs, it is erroneous to speak of the "discounted cash flow method" – Net Present Value is the correct nomenclature for what is arguably the major framework in public infrastructure appraisal.

There are major differences underlying the purpose and rationale of discounting, even within the field. The "social discount rate", as it is known, lacks a single strong theoretical *raison d'être* as it does in financial economics. Possible reasons for this are several: disagreement over a good yardstick, the disparate nature of the values discounted, intergenerational issues (not present in financial economics, given the long time horizons), no clear-clut way to include a risk premium (there is no public equivalent of CAPM to suit this purpose), environmental considerations, etcetera. The intractable nature of the discount rate quandary is aptly demonstrated by the oft-sounded call for a pragmatic approach and the widely seen practice of using a single, uniform rate for all projects.

The nebulous definition of risk in public infrastructure appraisal reveals itself not only through its general absence as a component of the social discount rate. Compared to project valuation in financial economics, risk analysis in public infrastructure appraisal has yet to develop beyond the inchoate state it finds itself in, and develop a uniform set of well-defined, time-honed risk appraisal methods that take stock of the statistical issues at play. The present dominance of sensitivity analysis and scenario-based methods falls far short of the mark, an issue that is gaining recognition within the field and even with European regulators. Granted, the high degree of project specificity, illiquidity and the prevalence of multi-decade time horizons might all but inhibit the risk analysis practice to reach a level comparable to that seen in financial economics; still, the leapfrogs in computing power and the ever-growing body of (international) experience offers some hope in this area.

Chapter 4 – Transport CBA Guidelines in The Netherlands

In the previous section, the principles of cost-benefit analysis were introduced, with a focus on transport infrastructure. Following a description of the most common techniques in the field, numerous "key issues" were touched upon, drawing on relevant (scientific) literature. In this section, we will expand upon this survey by describing the prevailing CBA guidelines as prevailing in The Netherlands, the country of our case study (to be covered in the next section).

While the cost-benefit analysis practice is the focus of this paper, it should be noted that Dutch regulators also allow other types of economic analysis to be applied to transport projects, either currently or in the past. Prior to the *OEI Leidraad* (to be covered shortly), an ill-defined mixture of cost-benefit analysis and multi-criterion analysis was employed (Annema, Koopmans, & Van Wee, 2007, Bristow & Nellthorp, 2000). Presently, while a CBA is mandatory before ground is broken and funds are committed, preliminary studies may take the form of a *"kengetallen kosten-batenanalyse"* (kKBA, meaning "key figures" cost-benefit analysis); when two more admissible projects offer comparable gain, a cost-effectiveness analysis (KEA in Dutch, for *"kosten-effectiviteitsanalyse"*) may be conducted to decide on preferability (Zwaneveld, et al., 2012). For the sake of distinction, the "full" KBA is at times referred to as "MKBA", for "*Maatschappelijke Kosten-batenanalyse"*, "social CBA".

4.1 Institutional Actors

Cost-benefit analyses for public projects on a national level are generally the domain of the *Centraal Planbureau* ("central planning bureau"), or "CPB". While not strictly part of the national government (Den Butter, 2010) it serves as an advisor thereof; tasked with calculating and forecasting the impact of policy proposals and producing economic projections, among other things (ibid). In time, it also became burdened with performing cost-benefit analyses (Koopmans, 2010) – a role which it had performed since its inception, barring a hiatus in the 1980s. Following adverse political reactions to the commissioning of the *Betuweroute* in the 1990s, two government ministries decided to draw up a common guideline for cost-benefit analyses of public (infrastructure) projects in The Netherlands. This eventually culminated in the "*OEEI Leidraad"* guideline, published in 2000 and subsequently renamed "*OEI Leidraad"* to reduce emphasis on the economic aspect of such analyses in the public eye (Koopmans, 2010). The final guideline was authored by the ministries in question, the CPB, and numerous private, public and academic parties (Eijgenraam, Koopmans, Tang, & Verster, 2000). The use of social cost-benefit analyses has since been made mandatory for all transport infrastructure projects commissioned publicly in the country (Heyma & Oosterhaven, 2005); with the CPB either conducting its own or evaluating external analyses, under the aegis of the national government. While differing opinions hold sway regarding the CPB's positioning, focus and style of communication, its cost-benefit analyses tend to be consistent with the multitude of second opinions given by other parties (Koopmans (2004) and Koopmans (2010)). In spite of this standing, the CPB's judgments are often ignored by policymakers (Rienstra, 2008), especially in the densely populated "Randstad" area of the country. A comprehensive study of contributing factors is conducted in (ibid); the incidence of unheeded CBA's varies per region, modality, project size and analysis phase, among others. Interestingly, a cost-benefit analysis of the CPB itself, while admittedly of a "back-of-the-envelope" nature, yields a staggeringly high benefit-to-cost-ratio in terms of averted social welfare loss (Koopmans, 2010).

4.2 History and structure of the *OEI Leidraad* guidelines

Since its inception in 2000, the OEEI guidelines have been examined and amended. In its original form, the full guideline frameworks comprised two parts, the *Hoofdrapport* ("main report") and the *Capita Selecta* ("selected readings"). It was evaluated in 2002 (Buck Consultants International, 2002), after which the name change to *OEI* was enacted. (Van Holst, 2010) In addition to "process-based" improvements ('t Hoen, Schol, & Wortelboer-van Donselaar, 2004), amendments were also suggested in the areas of direct and indirect effects, externalitities, and monetising environmental impact (ibid). Efforts were subsequently made to improve stakeholder communication, streamline the greater decisionmaking process, and address the methodical deficiencies of the framework – for instance, by delineating "indirect effects" in a more decisive fashion, devising a framework for monetisation of environmental effects (based on the "revealed preferences" approach as discussed in Section 3) and mandating the inclusion of distributional effects. This resulted in a succession of addenda published in 2004, chronicled in (ibid). These addenda are since considered of equal status to the original guidelines, which were not revised from their original inception (Rijksoverheid). Subsequent changes were since made pertaining to the context of the guidelines' application (for instance, with regards to "wet" infrastructure in the 2007 *SNIP* decision); these are however not reflected in the OEI framework themselves, rather established using separate policy documents.

4.3 General considerations of methodology

The OEI guideline framework concerns itself with answering three questions. First, does a project contribute to social welfare? (the *admissibility* question introduced in Section 3); second, what form should the project take (somewhat akin to the *preferability* question, albeit subordinate to the prior establishment of a project) and third, is financial support by the national government called for? Pains are taken to separate financial from economic return, establishing the OEI as firmly rooted in the latter camp – encompassing *all* factors affecting social welfare, relegating the financial return to a subquestion. While an effort should be made to monetise all said factors, the guideline recognizes the intractability of doing so (distributional effects and pristine nature are given as an example), recommending their inclusion as *"pro memorie"* – included, but not monetised. It is then left to the discretion of the decisionmaker to value and offset negative and positive PM effects to establish viability of the project. The analysis should include only "project effects", being those effects that stem from the project's establishment, compared to a "base case". This base case does not entail inaction or extrapolation of current policy; rather, a sensible alternative of the required investment funds is to be found. Failing that, the guideline states a risk-free investment at a real interest rate of 4%, hence devising an implicit IRR/ERR hurdle. All monetized costs and benefits are tallied on an annual basis and discounted, to arrive at a net present value for the project; IRR/ERR and B/C-ratio are not considered key indicators. (Eijgenraam, Koopmans, Tang, & Verster, 2000), though they show up in a number of (pre-OEI) appraisal reports.

4.4 Direct and Indirect Effects

Direct effects were originally defined as "a project's benefits that accrue to the owner or operator of an infrastructure segment, the users thereof and externalities resulting from the segment or its use" (OEI Leidraad, Deel 1). This definition was supplemented by the third amendment (Ministerie van VWS (Adviesdients Verkeer en Vervoer) & Centraal Planbureau, 2004) to encompass "direct network effects", referring to costs and benefits befalling other actors within the "transport system". Network effects will be considered in a later section, in order to maintain a section layout parallel to that of Section 3.

Indirect effects, by contrast, are those affecting others *outside the transport market* (emphasis added in the addendum) than the project's users and operators. In this regard, the guideline describes competitive effects, cross-border effects and redistribution of social welfare. It is also noted that the line between direct and indirect effects is often frayed, and that indirect effects may take the form of direct effects transferred to third parties (in this case, the effects are merely distributive and do not add to aggregate social welfare). When redistributive effects cross national boundaries, the net national effect may not be zero. At any rate, a causal relationship between an indirect and a direct effect must be established to justify its inclusion (Eijgenraam, Koopmans, Tang, & Verster, 2000). The guideline states a preference for modelling these effects (as opposed to a macroeconometric approach, using case studies or literature research), possibly using a "yet to be constructed" general equilibrium model. Particular indirect effects will be covered later in this section.

4.5 Charging versus Costs – or Finance versus Economics

The presence of social welfare effects expands the CBA beyond a mere exercise in financial "bookkeeping" – indeed, this chasm is the subject of this paper. Nevertheless, OEI-compliant analyses ought also comprise a financial analysis (*"bedrijfseconomische analyse"*) to evaluate the project from a purely private standpoint, in the fashion described in Section 2 above. There are several reasons for this: to establish the required rate of government financing, to scrutinize the viability of a public-private partnership and the requirement that the project planner or sponsor estimate an expected user charge or price for use of the infrastructure. The latter, arguably important from the point of social welfare and justice, allows the project's strength vis-a-vis competing modes of transport to be quantified in the "main" CBA (Eijgenraam, Koopmans, Tang, & Verster, 2000). The guideline emphasizes that the financial analysis is an alternative way of looking at the project, and not a subcomponent of the general CBA – if operating revenues of a particular infrastructure facilities were included with other project benefits, double counting would occur, as some of the (direct) benefits will already be "priced in" by its users. Hence, to avoid the unintended double-counting of an effect that is chiefly redistributive, benefits may only be tallied with the difference in price between the new project and its existing alternatives.

Very few guidelines as to the characteristics and constraints that inform this analysis are given by the authors. Of note is the (explicit) recommendation to use the same discount rate as the "main" CBA in spite of a higher rate often employed by private investors.

4.6 Valuing Time

In an interesting departure from the research quoted in the previous section, the OEI used questionnaire data as a starting point for travel time valuation (the guideline notes alternative methods, e.g. based on wages, but elects to use this method). This data was obtained in 1997 from "over 4100" nationals, over sixteen years of age, and split by modality, purpose and income group, and recorded in Dutch guilders per hour (ranging from f 9.30 to f 50.20). A similar categorization in modality and purpose is withnessed in, for instance, (Bristow & Nellthorp, 2000) and (Belli, Anderson, Barnum, Dixon, & Tan, 2001); a split based on personal income adds to this distinction. For trips with a business purpose, results were altered to incorporate employer as well as employee time value (Eijgenraam, Koopmans, Tang, & Verster, 2000). Rather than conducting a new survey every year, these values are extrapolated using more conventional methods: business trips are assumed to grow at a rate similar to wages, and leisure time and commuting trips at the growth rate of the consumer price index. As stated in the addendum (Ministerie van VWS (Adviesdients Verkeer en Vervoer) & Centraal Planbureau, 2004) these values are subsequently corrected for inflation, so as to express them in real terms (the base year currency). The addendum goes on to note that the assumptions of income elasticity inherent in this methodology are probably flawed, and that its techniques of proxy estimation for freight time savings are incomplete as well. In a pan-European examination of value of time, Bristow & Nellthorp place The Netherlands at the higher end of the spectrum, at €22/hour for an hour of business-time car travel (2000). This is second only to Finland, at €23, and on a level equal to Denmark. Citing its 2004 study, the European Commission reproduces travel time savings valued in 2002 euros for all then-member states plus Switzerland (European Commission, 2008). The Netherlands is at the higher end for all modalities, exceeding the EU25 average in line with its higher per-capita GDP.

An example of how to put these direct gains in travel time, or *travel costs* in general, to use is provided in Chapter 8 of the OEI Guideline. A decline in travel costs, for instance due to a road widening, for the use of a particular stretch of transport infrastructure will benefit existing and new users alike. Existing users are simply those travelers whose willingness to pay was already adequate to cover the travel costs in the old situation; new users, on the other hand, deemed travel too expensive (it should be noted that terms like "pay", "costs" and "expensive" pertain to the wider definition of economic means and do not necessarily bear a financial meaning) in the old situation, choosing to use the infrastructure only in the improved, "cheaper" situation. Members of the former group stand to benefit to the full extent from this decrease in costs, presumed they will continue using the infrastructure after the improvement (a reasonable assumption in the face of rationalism). Newcomers, on the other hand, constitute those along the WTP gradient starting *just below* the former travel costs (i.e., in the former situation, their willingness to pay was infinitesimally smaller than costs) ending marginally above the new travel costs. Their gain, then, is on average equal to half that of those who used the infrastructure previously. Assuming no changes to the demand curve, the total increase in benefits to all users is then equal to $\frac{1}{2}(Q^0 + Q^1)(P^0 - P^1)$, in other words, half the sum of new and former demand volumes times the change in travel costs. This is known as the 'rule of half' (Button, 1993).

4.7 Valuing Employment

Employment effects of infrastructure projects are covered as an indirect effect in the OEI guideline. It chimes in with the European Commission's observation (European Commission, 2008) that employment effects are an oft-touted benefit of infrastructure projects, however, it is less sanguine on the extent to which such effects stand up to scrutiny. In an economy operating at full employment – a hypothetical extreme, perhaps, yet closer to reality in the Netherlands than in most countries [how does one build anything new when there's no people to employ left?] – a project will, by lowering transport costs or time – lead to increased labour mobility. This, in turn, allows those already in the workforce to widen their potential range of employment possibilities, allowing them to take on higher-paying jobs than before, as employers jostle for newly-available employees. In the end, wages rise across the board (with debatable net effects, given exports are now less competitive), and firms lowest on the "productivity ladder" cease production, leading to an increase in social welfare by an entirely different means than envisioned originally.

In an economy at less-than-full employment a similar effect may result, for two reasons. As the composition of the labour market is not uniform, unemployment might be especially manifest in certain groups. For instance, unemployment might exist chiefly among the unskilled, while skilled labour is still in short supply. In this case, the lack of skilled workers will constrain production and thus a growth in employment, *unless* the project allows a relatively greater amount of unskilled people to find work. Even if it does, inflexibilities, friction and institutional rigidities will counteract to an extent the long-term creation of more jobs (this is further explained in the addendum), once again leading mostly to a rise in wages. The only net addition to employment consists of those previously unwilling to work due to commuting costs; however, this does not constitute a net addition to *social welfare* – the leisure time they give up needs to be subtracted from their newly-gained wage, as well as the commuting costs they would incur.

All in all, the authors of the guideline and its addenda are sceptical towards any real increases in employment resulting from the commissioning of new infrastructure projects. Citing the general intractability of estimating any possible increase, no guidelines are provided beyond the usual caution to avoid double-counting. This is generally in line with the research examined in Section 3.

4.8 Valuing accident prevention

Neither the OEI guideline nor their addenda offer anything in the way of concrete guidelines for valuing accident prevention. Such effects are grouped under externalities, which will be covered later in this section. Bristow and Nellthorp wrote in their 2000 paper that The Netherlands refrains from valuing human suffering in its cost-benefit analyses (note that their research concerns the pre-OEI period), as does Greece, leading to a much lower cost compared to most other "core" EU countries. They arrive at a "total cost per **fatality**" of € 113,000 in 1994 euros. (Grant-Muller, Mackie, Nellthorp, & Pearman, 2001) et al note this as well (using the same data), noting that the Dutch (pre-OEI) practice involves placing human costs in the Multi-Criterion Analysis or MCA, separate from the CBA.

4.9 Estimating demand or usage

Calculation of the effects mentioned in this paper is in large part dependent on estimated traffic flows, as the guideline states. Admittedly, these are in turn dependent on usage charges set by the operator, rendering accurate estimation a simultaneous process. The guideline calls for a behavioural model to be employed to this end, explicitly modelling relevant causal relationships and avoiding double-counting to accurately reflect usage patterns. Similar to (Belli, Anderson, Barnum, Dixon, & Tan, 2001) discussed previously, the focus is on traffic resulting from lower transport costs; the OEI guideline defines "generalized transport costs" as comprising monetary outlays, travel time, frequency, comfort and the ability to work while travelling. These costs are then monetized, added up and compared to those previously incurred by the (potential) traveller. However, the valuations thus used may differ from the traveller's implicit value ascribed to these (immaterial) factors, and may interact with one another.

In its own cost-benefit analyses, the CPB often commissions or utilizes a (behavioural) model, or at the very least a set of prognoses, from a third party, often a for-profit consultant. While the model's outcomes are reproduced in the final report, the model itself is obfuscated from public view and generally not available for public scrutiny. Examples of this can be found in (Centraal Planbureau, 1995), (Koning, Verkade, &

Hakfoort, 2002); in (Centraal Planbureau, 2000) demand prognoses were sourced from Intraplan GmbH and detailed description of their provenance (e.g. a model) is given. In (Saitua Nistal, 2004), though the "global" demand model was developed externally, a detailed model is described and used to model traffic flows to specific ports within this "global" range.

It should be noted that the OEI framework exhibits a significant focus on passenger traffic, as opposed to freight, when it comes to demand estimation. The guideline's authors recognize this, stipulating that, due to the relatively small size of The Netherlands and its function as a European entrepot, the benefits of freight infrastructure improvements are mostly felt across borders.

4.10 Externalities and Environmental Considerations

As summarised in (Grant-Muller, Mackie, Nellthorp, & Pearman, 2001), prior to the establishment of the *OEI Leidraad*, Dutch analyses did not quantify environmental impact in monetary terms at all, including only a project's noise and local air pollution effects in the cost-benefit analysis (several other environmental effects were considered qualitatively in the multi-criterion analysis). This has changed with the introduction of the *Leidraad*; its authors explicitly state the importance of including externalities, and pricing them whenever possible. The guideline defines external effects as "unpriced efficiency effects" on "third parties, i.e. others than the project's operators and users", with the former definition considered the primary constraint – not all effects on third parties are external. In fact, "priced effects" – those resulting from lower transport costs arising from the project's use – affecting third parties are explicitly excluded from this category, rather considered "indirect effects" as covered above. The guideline clarifies this by stating that "external" in its definition comprises external *to the market*, not *to the project*.

While the guideline refrains from explicitly recognizing or delimiting the various types of external effects, asserting that these are too project-specific, the guideline's text reveals a broad categorization on several occasions. For one, the document's indices refer to the environment, nuisances (*"hinder"*) and safety. In the relevant chapter, pricing techniques are introduced for travel time (not an externality according to the guideline, but a direct or indirect effect), noise, local and global emissions, safety (already considered in this section to parallel Section 3's layout), nature and scenery – both use and non-use ("existence") values – and (global) climate change. On the notion of **positive** externalities, the guideline states that, for transport infrastructure, true positive externalities are rare, save for network effects. These are covered in a different section of the guideline, but will be covered hence in a similar fashion as in Section 3. As this only leaves environmental externalities to be discussed, we will do so in the remainder of this subsection.

Broadly defined, environmental effects are understood to comprise noise, emissions, pollution of soil and water, and the impaired quality of pristine nature and scenery, affecting both its existence and its potential use. The original guideline refrains, perhaps surprisingly, given the fraught nature of this endeavour, from providing any methodological advice on delimiting the scope (spatially and temporally) of any environmental effects that may occur as a result of the project's operation; its sole focus is on valuing any effects deemed project-related. In this, it largely runs parallel to the two "schools" of methods described in Section 3: revealed preference (encompassing hedonic pricing and the travel cost method) and stated preference (by means of questionnaires using either contingent or conjoint analysis). While the guideline asserts the superiority of the former, it makes no specific recommendations besides providing example situations in which each may be used (Eijgenraam, Koopmans, Tang, & Verster, 2000). Furthermore, it recommends that the costs of preventing or mitigating the effect be studied as well, noting that it may differ greatly from the willingness-to-pay of those affected. In this way, a policy of compensation or prevention may be devised.

The fourth addendum (Ruijgrok, Brouwer, & Verbruggen, 2004) elaborates on the project effects related to soil, water and nature quality, addressing the hitherto deficient issue of identifying and delimiting environmental impacts. It provides a five-point plan to this end: first, a project's **physical** effects are to be established, followed by the identification of the function or aspect of the ecosystem that is affected. Then, this effect is to be expressed in terms of the (amounts of) "goods and services produced by the natural environment". These effects are then quantified and finally monetized. In esteeming a project's *total economic value*, both the project's *use value* and *non-use value* ought to be considered. On the whole, the Dutch guidelines to a large extent resemble those propagated by the European Commission in its 2008 policy document (European Commission, 2008).

Interestingly, neither the *OEI Leidraad*, its addenda or abovementioned EC document address the issues of time horizon, intergenerational equity and discounting recognized in the literature consulted in the previous section of this paper. The addendum briefly makes note of these, stating that they are too complicated to be included in the analysis. In the CBA example provided, all environmental effects are discounted at the 4% benchmark rate over a relatively short time period (< 30 years).

4.11 Network effects and induced demand

In the *OEI Leidraad* pantheon, network effects – understood to be effects on "other agents" **within** the transport market – are considered part of a project's indirect effects. Within that category, network effects are distinct in that they are the **only** indirect effects included in a 'partial CBA', which excludes externalities and non-network indirect effects (we are predominantly concerned with the 'full' or social CBA in this paper).

Stopping short of mandating a particular means of calculating network effects, the *OEI Leidraad* recommends the use of the 'rule of half', described above: assuming constant, linear demand curves, total gains *across the* *network* are equal to half the product of the sum of old and new demand and the change in travel costs *for all "spokes"* (origin-destination combinations) in the transport network, or

$$0.5 \sum_{m \epsilon M} (Q_m^0 + Q_m^1)(P_m^0 - P_m^1)$$

for all three groups of travelers: existing users of the new infrastructure, users switching *to* the improved infrastructure from alternative routes or means, users who continue using said alternatives (whose costs are now lower due to collapsing demand) and new users, whose WTP was previously insufficient to travel at all. While this provides a workable and feasible method of incorporating demand volumes and time savings in a CBA, the issue of establishing and delimiting the nature and amount of "spokes", alternatives, and cost savings for each are deemed project-specific and not elucidated in the guidelines.

On the issue of induced demand, the *Leidraad* notes that new, previously non-traveling users were engaged in alternative, less-beneficial activities or occupancies prior to their incipient use of the infrastructure; this previous engagement might have had indirect effects that are now forgone. Establishing the nature of these indirect effects is required for a full CBA to take place. New travelers (or freight movements) can either follow the existing "spread pattern" of economic activity, or alter this pattern (for instance, by allowing businesses to move to a more convenient location). Another effect noted by the authors is the possible reaction by a modal competitor to the change in travel cost or modality; the construction of the Channel Tunnel, for instance, lead incumbent ferry companies to accelerate their investment in faster vessels, undermining the Tunnel's demand. The authors even state this as a possible reason for consistent overestimation of project gains demonstrated *ex post*.

4.12 Price level effects

The *Leidraad*'s authors note the difficulty in establishing the nature and amount of price-level effects on national welfare, citing the required incorporation of an "allocation model" into the demand predictions, noting that attempts at doing so have largely been fruitless. Unfortunately, such conjectured changes are often stipulated as key reasons for the commissioning of a specific infrastructure project. Usually, such gains are stated qualitatively.

4.13 Discount rate considerations

The *Leidraad* makes mention of a "government-mandated" real discount rate benchmark of 4% for risk-free projects (Eijgenraam, Koopmans, Tang, & Verster, 2000). The possibility of establishing a risk premium to add to this rate, analogous to the common practice in financial economics (see Chapter 2 of this paper), is discussed but no particular methodology or yardstick figure is recommended. The authors nevertheless recommend against using the risk-free rate with a "long" time horizon. In another section of the *Leidraad*, the authors state that 4% is the mandated rate for all government products since 1995, regardless of risk (Eijgenraam, Koopmans, Tang, & Verster, 2000). The terms *"discontovoet"* and *"maatschappelijke discontovoet"* (social discount rate) are used interchangeably, revealing the authors' abstinence from drawing a clear distinction as seen in literature (see Chapter 3). Both are set at 4%. Inflation is not explicity taken into account, in spite of defining this rate as "real".

The guideline recognizes that this is at odds with European practice, with discount rates ranging from 3% in Germany to 8% in France (Dings, Leurs, & Bleijenberg, 2000). The issue of discounting possible adverse effects (see Chapter 3) in the future is noted in passing, but not acted upon. Declining discount rates, such as advocated in literature pertaining to sustainability and intergenerational equity, are wholly absent. In an addendum (Ministerie van VWS, Ministerie van Financiën, Centraal Planbureau & Rebelgroup, 2004), the rationale for the 4% rate is given as being equal to the average real yield (effective interest rate) of long-term Dutch government bonds. In 2007, a multilateral working group advised a new real risk-free rate of 2.5%, as a result of lower yields in the bond market (Werkgroep Actualisatie Discontovoet, 2007). This advice was adapted by the government. (Rijksoverheid, 2008)

In the addendum on valuing project risk, the CPB explores possible avenues for incorporating a measure of project risk in the CBA (Ministerie van VWS, Ministerie van Financiën, Centraal Planbureau & Rebelgroup, 2004). It is advised that *macroeconomic risks* be incorporated in the discount rate, whereas "diversifiable risk" and "special events" are captured by altering the cost/benefit streams themselves, a practice generally advised against in financial economics. Macroeconomic risk is seen as analogous to "market risk", the general methodological context in "private" financial valuation (obviously, there is no liquid "market" for similar infrastructure projects, however). As such, the authors suggest estimation of a beta coefficient, to be multiplied by a **3% risk premium** to arrive at a suitable project discount rate. This beta coefficient is to be established by statistical analysis, simulations using a model or "previous experience". The first and last of these methods require the presence of a "market", or "universe" in financial parlance, of comparable project data. In its absence, the authors recommend that a **7% discount rate** be used, equivalent to a project with a beta of 1 (exactly correlated with macroeconomic risk). Examination of CBA practice reveals that, citing the absence of a risk valuation, evaluators in the past used a 4% discount rate (NEI (2000), Centraal Planbureau (2000)) without incorporating a risk premium.

This former absence of an explicitly valued risk premium gradually gave way to a risk markup of 3%, coinciding roughly with a drop in the official risk-free rate described above. These countervailing effects led to the actual discount rate used in project CBA's staying largely the same throughout the lifetime of the *Leidraad*, as the figure shows. To gauge the rationale behind the 4% and 2.5% yardsticks, ten-year real yields (i.e. officially published yields minus published inflation) on Dutch government bonds were graphed over the lifetime of the *Leidraad*, with the "official" OEI rate shown and actual discount rates employed for 22 CBAs conducted during the period:

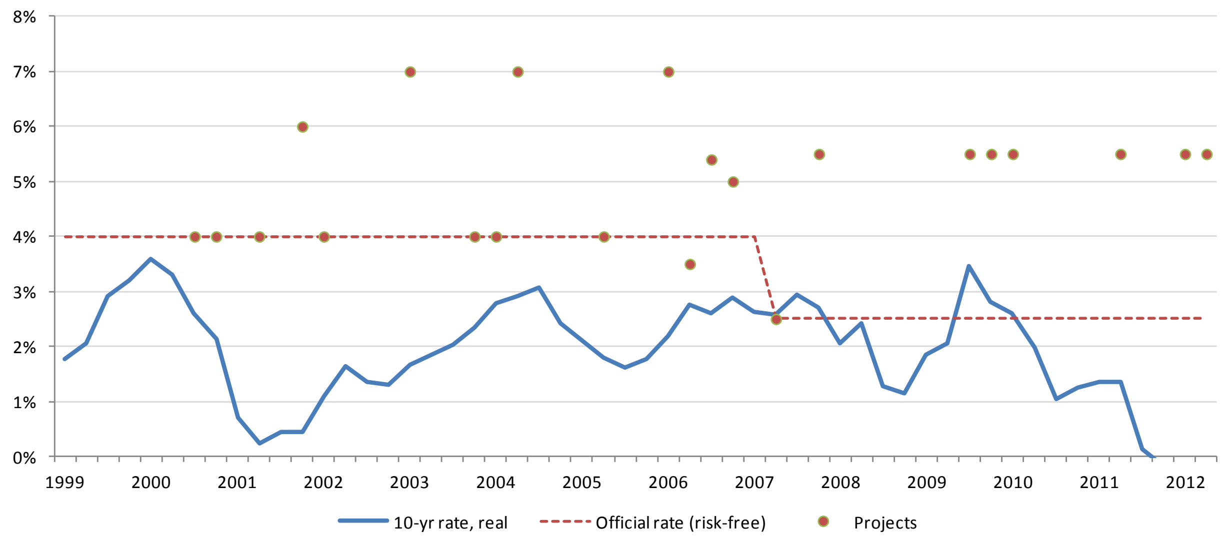

Figure 1: Project discount rate employed, versus ten-year Dutch borrowing rate (corrected for inflation) and OEI rate (no risk)

Clearly, the bond-yield rationale doesn't hold for the 4% figure, though the 2.5% benchmark seems closer to reality. Before 2007, most surveyed projects used the 4% risk-free rate, whereas from 2007 onwards **all** projects followed the 2.5% risk-free rate with the 3% risk premium 'rule'. Apparently, project risk was structurally disregarded in the majority of cost-benefit analyses before 2007, whereas afterwards all projects were deemed to have a risk profile exactly commensurate with "the market" (macroeconomic conditions). This has three important implications: before 2007, projects were most likely overvalued given their **actual** risk profile; project risk is arguably not esteemed properly (giving rise to a beta of 1 for all projects – a debatable assumption considering the differing nature of the projects surveyed) and finally, for the last five years projects have consistently been valued at a higher discount rate than before. In a sense, the shift outlined reflects a move from the 'social discount rate' concept, where 'society's cost of capital' is used as a metric, to a more financial philosophy – the discount factor is simply the time value of money, plus a premium for non-diversifiable risk. The CPB explicitly disparages discounting costs and benefits at separate rates, as advocated in Mun's recommendations discussed in Chapter 2 (Verrips, Stolwijk, & Hamers, 2009)

4.14 Time horizon

The *OEI Leidraad* recognizes the issues plaguing accurate project duration as already identified in Chapter 3: the project may have a certain 'life' (or several) but may give rise to costs and benefits far into the future

(Eijgenraam, Koopmans, Tang, & Verster, 2000). Rather than drawing up a guideline to properly delimit this horizon, the authors shift their focus to the relationship between discount factor and time horizon employed, advising that the time horizon be curtailed lest future costs and benefits provide too much weight. This problem is especially manifest when low discount rates are employed. As we outlined in the previous subsection, this is usually the case; the authors calculate that, at the 4% social discount rate, common before 2007, costs or benefits thirty years 'away' have weighting of 31%. Long evaluation horizons may therefore only be used when the discount rate is sufficiently high to discount possible future risks. This means of approaching time horizon is starkly at odds with transport economics literature, where 'fudging' the time horizon is considered perilous. In financial economics, 'cherry-picking' the time horizon is equally uncommon; usually, time horizons are short (five to ten years) are employed to mitigate the effect of erroneous predictions and reflect common investment (mandate) horizons.

In an addendum to the *Leidraad* (Ministerie van VWS, Ministerie van Financiën, Centraal Planbureau & Rebelgroup, 2004) the CPB recognizes the problematic nature of this method. Using arbitrary cutoffs skews project valuation and can make any project seem viable (the authors cite the *Betuwelijn* project in the 1990s as an example). Ideally, very long time horizons should be used (fifty years is given as an example) with discount rates that accurately reflect project risk. A survey of Dutch CBA's conducted by the CPB revealed an average time horizon of 26.8 years, roughly in line with the EU average of 26.6 years (European Commission, 1997). Analyses conducted by third parties, checked by the CPB, used a greater variety of discount rates – from one century (Rijkswaterstaat Noord-Holland, 2012) to eternity (Havenbedrijf Rotterdam N.V., 2003).

4.15 Probability and Risk Management

Estimating and controlling risk receive ample treatment in the *Leidraad*. On a general level, the authors discern two distinct strands of doing so – increasing the discount factor commensurate with risk or (preferably) explicit recognition of project risks by means of scenarios or simulations. They go on to stress the importance of accounting for risk, and caution against merely touting a single project value as if it were riskless (Eijgenraam, Koopmans, Tang, & Verster, 2000). Altering ('fudging') cost-benefit streams to reflect risk is preferred over increasing the discount rate (society is judged risk averse), in contrast with prevailing practices in finance. As described above, curtailing the time horizon is also seen as a risk mitigation strategy. Furthermore, "phasing" is raised as a way to limit risk exposure: when circumstances change, the project may be altered or scaled back before the full outlay is made – as the guideline states, this constitutes a 'real option'. The guideline provides brief theoretical background on real options, as well as a case derivation using a decision tree. We will revisit this particular subject in the next chapter.

The *Leidraad* describes a typology of project uncertainties as sources of risk: *predictive uncertainty*, stemming from the fundamentally uncertain prediction of explanatory variables, *estimation uncertainty*, a result of calibrating model parameters wrongly, and *structural uncertainty*, arising from a flawed match between the model and reality. The former two are to be accounted for by sensitivity analysis – the well-known practice of varying the value of key inputs to gauge their effect on outcome (in this case, project NPV); the effect of the latter, while intrinsically complex to address, may be somewhat abetted by employing scenario analysis. Scenarios tend to be shared across projects, are based on macroeconomic predictions, sometimes including regulatory shifts as well.

To assess the extent to which the various guidelines on risk analysis are incorporated in actual CBAs, a sample of 24 cost-benefit analyses was taken over the 1997 – 2012 period. Most were conducted by the CPB with a minority conducted by outside parties under the *OEI Leidraad* aegis. Three predate the guideline.

Methodology	Incidences in sample CBA's
Sensitivity Analysis	16
By factor:	
Discount rate	*5*
Demand	*5*
Investment Outlays	*4*
Time Horizon	*2*
Project-specific factors	*7*
Scenario Analysis	13
By nature:	
Macroeconomic, two scenarios:	*4*
Macroeconomic, three scenarios:	*6*
Sector-specific, any number:	*4*
Monte Carlo Simulation	1
Real Options Analysis	0

Table 3: Risk analysis methods by incidence

4.16 Chapter conclusion

The cursory examination of the *OEI Leidraad* reveals it to be broadly in line with transport economics theory, with some notable exceptions. For one, there are disparities in overarching philosophy on the "purpose" of project appraisal: to the key questions of admissibility and preferability it adds a third: the degree to which government support is required. The strong emphasis on the exact nature of the "base case" as an alternative deviates from "clear-cut" valuation of net benefits to society, making comparison across projects, regions and periods (of appraisal or construction) difficult. Both are furthermore at odds to some extent with financial project appraisal, where the "base case" usually has zero value and government involvement is at best a given, an input to the model as in PPP and BOT contexts. There is a strong preference for the NPV method, in line with both theory areas.

From a methodological point of view, concerning the identification and valuation of effects, the *OEI Leidraad* agrees with theory on most accounts. Besides the obvious differences of approach in valuing time savings – using questionnaires instead of opportunity cost – and accident prevention, the relegation to external models of demand estimation, network effects and price level effects lends little insight into the valuators assumptions and methods for these effects, impeding any comparison to established theory. Most, if not all of these models are as of yet unpublished and unavailable for public scrutiny – a questionable situation, considering the public's interest in sound CBA practice.

Interestingly, the application of the NPV method differs from common practice in both financial and transport economics. The rationale for establishing a proper time horizon appears not to be based on investment horizon or project lifetime, but on its effect on ultimate project value. Suggestions for setting a proper (social) discount rate were revised in the addenda, reflecting a change from an (ill-motivated) measure of "society's cost of capital" (as seen in welfare economics) to a simplified application of the CAPM method of financial economics provenance. The implications of this sudden contrived "jump" are daunting.

The state and practices of risk analysis in the *OEI Leidraad* mirrors that in the field of transport economics to a large extent. Sensitivity analysis and scenarios are the prevalent "tools of the trade", with little to no mention of switching analysis. All methods suffer from an obliviousness to probabilities and correlation and are to an extent susceptible to the appraiser's decision to use a certain scenario or include a certain variable, giving rise to a great variety of risk analyses as presented in the table above. In spite of the move towards including a risk premium in the discount rate, there has so far not been a visible effort of any kind to estimate or even argue for a certain beta coefficient – it is always assumed to be unity, which is no doubt far off the mark in many cases. Furthermore, no "feedback" between risk-through-discounting and conventional risk analysis methods – such as scenario analysis – is given in the analyses examined for this section.

In appraising the OEI practice, two things should be borne in mind: one, that the *Leidraad* was born of a perceived lack of a clear, uniform appraisal method in The Netherlands, and that it may therefore take more than the twelve years hitherto for its full effect to come into force, second, that Dutch regulators – from whon the CPB is administratively sequestered – have a history of ignoring CBA outcomes, complicating the effect an improved appraisal practice might have on public welfare and possibly affecting the perceived need for future improvements thereof. Finally, while the guidelines also apply to CBAs conducted by third parties, a reading of such appraisals reveals considerable leeway granted to these parties in terms of presentation (level of detail and disclosure), time horizon and risk management.

Chapter 5 – Improving OEI-based Infrastructure Appraisal

Having examined transport infrastructure appraisal from a "private" (financial) and "public" (welfare economics) standpoint, certain things have come to light that may aid the conduct of future project evaluations under the OEI framework as mandatory in The Netherlands. Besides the obvious harmonization of theory and practice (as amply highlighted in Section 4) the opportunity presents itself to employ techniques hitherto wholly or mostly unseen in transport infrastructure appraisal: real options valuation and Monte Carlo simulation. The benefits to improving risk management (identification and mitigating) have been amply recognized in all fields examined, as well as by the authors of the *OEI Leidraad*. Building on the theory presented in Sections 2 and 3, we shall describe how and which risk-management techniques may be used and in what way this will aid the practice of project appraisal towards furthering stakeholders' interests. The Dutch *HSL-Zuid* project is used as a real-life case, to identify current risk-analysis techniques and as an example of how real options may be used in practice.

5.1 Options for OEI

Due to its exclusive use of NPV (*"netto contante waarde"* or *NCW*) as central methodology underpinning cost-benefit analyses, OEI-compliant CBA's suffer from the same deficiencies as identified by the real options literature cited in Section 2. Central to these is the disregard of any flexibility, as the NPV method presupposes a completely static cashflow pattern following the investment decision. Not only is the fixed nature of these forecast cashflows in itself a source of uncertainty, it also assumes an unnecessarily rigid approach to project management and will hence understate project value in cases where such flexibility actually does exist. Arguably, this applies to most transport infrastructure projects – valuation horizons are usually long (generally several decades), project parameters abound, and investment and commissioning usually have a phased character. Apparent flexibility not 'captured' by NPV may be included by broadening the analysis to include real options valuation techniques. The *Leidraad*'s authors recognize this as well, and include a small subsection in the *Capita Selecta* part of the guideline (Eijgenraam, Koopmans, Tang, & Verster, 2000) introducing real options in brief and including a short case demonstrating a simple *Time To Build* option as well as a more complicated sequential compound option consisting of *Chooser*, *Time To Build* and *Expansion* options. In both cases, the binomial lattice method is used. The section emphasizes the existence of real options in investment timing (phased investment, giving rise to *time to build* or *delay* options) in a point infrastructure (e.g. port facilities) context. It concludes by noting some of the disadvantages to using real options valuation in a staged-investment context.

It should be noted that optionality is always a factor in project appraisal and management; real options valuation does not change the flexibility inherent in such projects. It is, however, uniquely capable of valuing the options overlooked by "traditional" valuation methods, and in that affords a more complete view of project reality. For instance, when the *Afsluitdijk* seawall was constructed in the first half of the twentieth century, provisions (such as extra bridges and ground levelling) were put in place for the eventual construction of a railway line. This constitutes a clear-cut American call real option on profitable railway exploitation, at the expense of these provisional constructions (the "option premium"). Likewise, setting aside surplus acreage during land reclamantion projects has an optionality component; even the "overpasses to nowhere" that dot the landscape in some regions have at least some merit from an optionality standpoint.

5.1.1 Accounting for demand flexibility using real options in infrastructure

Notwithstanding aforementioned inclusion of real options valuation in the official guideline, no CBA has ever been published incorporating real options valuation explicitly. Supplementing our cursory foray into real options valuation, this subsection will demonstrate the use of the 'lattice' method to explicitly value the flexibility inherent in infrastructure operation. As noted several times in this paper, as a driver of most costs and benefits, demand is a significant factor in infrastructure project appraisal, if not the most influential on project value. Given the uncertainty with which demand prediction is fraught, it stands to reason that the ability to act in the face of developing demand adds value to the project; for instance, the infrastructure in question might be expanded to serve a higher demand level, scaled down to save costs or dismantled and sold entirely, whichever is most profitable. As shown, the net present value method that underlies conventional cost-benefit analysis has no way of incorporating such flexibility.

Mun describes the case of a manufacturing firm that faces similar options, compounded in an 'option to choose' (2006). It consists of American options (exercisable at any time) to expand, contract, and abandon production, with the fourth "option" of not exercising any and to continue production. This situation is highly adaptable to the many types of (transport) infrastructure with a high variable cost component responsive to demand – public transport, power generation, ports, airlines and the like. Using *binomial lattice analysis* it is intuitively shown how project value can decline or increase as a result of external (demand) conditions, without sacrificing analytic acuity (as lattice depth increases, the calculated value converges on that of a closed-form solution). This 'portfolio' of options succeeds in limiting the downside of the project to its salvage value (instead of assuming 'forced' loss-making operation) while allowing its managers to ramp up operations – at additional cost – when profitable. In the example, the range of project values, as a percentage of initial project NPV, shifts from 47.2% – 211.7% to 100.0% – 255.2% as a result of properly exercising any of the four options. In other words, any downside is completely eliminated and the upside is increased notably. Using backward induction with risk-neutral probabilities (a purely theoretical construct that, through "simulating" Brownian motion, models flexibility) the value of this real options portfolio is 19% of total project value as estimated using the NPV method. Once more, the initial value range is unlikely to actually occur in practice – it only would if project management were completely apathetic to any project developments. Of a certainty, such absolutely inflexbility is highly unlikely to be observed in any real-life case; therefore, "static" NPV analysis provides an incorrect picture of the likely range of project values. More likely, projects that are valued using static NPV are managed by exercising real options embedded in the project.

5.1.2 The case for dual signalling on the HSL-Zuid: a real options approach

In modern times, railway construction involves more than laying track and building bridges and catenary: signalling systems are a crucial part of contemporary rail infrastructure. It should be noted that a signalling system also entails significant changes to the rolling stock, which has to be adapted and certified for interoperation with any signalling system it might encounter. With the *HSL-Zuid* high-speed railway, Dutch planners decided on exclusive implementation of the newly-developed and unproven ERTMS (European Railway Traffic Management System) for signalling along the trajectory, instead of installing the older ATB system used on conventional railways in the country (Railway Gazette International, 2008). In a sense, this constituted forgoing a sequential switching option that would've been brought about by installing *both* systems at commissioning, using tried-and-tested ATB until ERTMS was sufficiently mature for a smooth transition. So-called 'dual signalling' of this kind is presently operational on the Amsterdam – Utrecht corridor and will be installed on the "Hanzelijn" trajectory presently under construction. Full ERTMS operation on the HSL-Zuid was expected in 2008 (Nederlandse Spoorwegen, Prorail and Belangenvereniging Rail Goederenvervoerders, 2008), with an iterative implementation that allowed domestic services to run in 2007 while cross-border implementation differences were ironed out (Jongeneel, 2007). In the end, signalling issues pushed commercial operation of any sort back to september 2009 (Railway Gazette International, 2009), even though the physical trackbed was finished at the end of 2006 (Railway Gazette International, 2006).

A stylized version of this case lends itself well to real options analysis. Installing ATB in 2006 effectively "purchased" a switcher option that would allow at least some degree of service on the HSL-Zuid from 2007 on, until ERTMS implementation had sufficiently progressed for a switch to be made. Even the modest of services would have brought about a portion of the benefits foreseen in the CBA with only a marginal increase in costs (considering the multi-billion overrun in construction outlays the project faced). Not installing ATB curtailed this flexibility, with operation dependent on timely ERTMS implementation. For the sake of simplicity, we assume that the chance of track and trains becoming ERTMS compliant is $\frac{1}{3}$ in any given year; due to higher service speeds and a lower likelihood of accidents, ERTMS-based services result in higher benefits compared to conventional train service. As both decisions entail transitioning to ERTMS-only operation at some point, no switching costs are assumed. Once ERTMS becomes operational, we assume it remains so (at least for the duration of the analysis) and no switch to ATB is possible. This allows us to construct the following non-recombining lattice of cashflows:

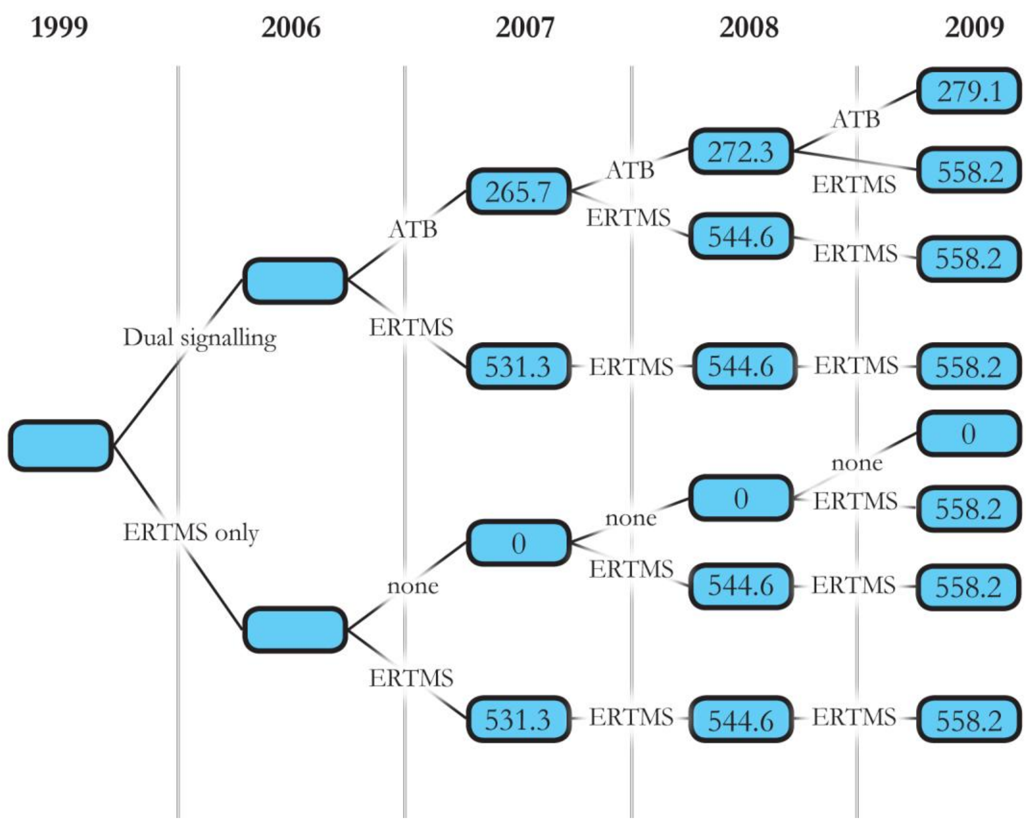

Figure 2: yearly cashflow lattice, pruned to exclude unfeasible nodes

Nodes display <u>total annual benefit net of running costs</u> (**not** net of construction costs) for that year. These were sourced from the original 1994 CBA for the HSL-Zuid (note that this analysis predates the OEI framework), annualised and converted into 2006 euro amounts (using Dutch CPI figures from the Central Statistiscs Bureau) using the report's own estimation of 2.5% annual benefit growth. Note how this differs from project NPV, which is the *total* value of the project <u>including future years</u>. Our calculation puts the estimated 2007 benefit of running the "maximum service type" (*"maximale variant"*) at €531,3 million in 2006 euro's. For simplicity, we assume that the best service attainable using the ATB system (which allows a maximum running velocity of 140 km/h) leads to only half the annual benefit amounts. In both cases, benefits are assumed to grow annually by 2.5%. Unattainable nodes – such as those representing a switch back to ATB, which we rule out – have been pruned.

With the parameters given above, we can now value both paths down the decision tree – dual signalling and ERTMS-only. Assuming a 5% discount rate as given in the original (pre-OEI) CBA, we follow the guideline's own simplified method for valuation to arrive at the following value lattice (node values contain estimated net benefits for the year in millions of euro's, discounted to 1999):

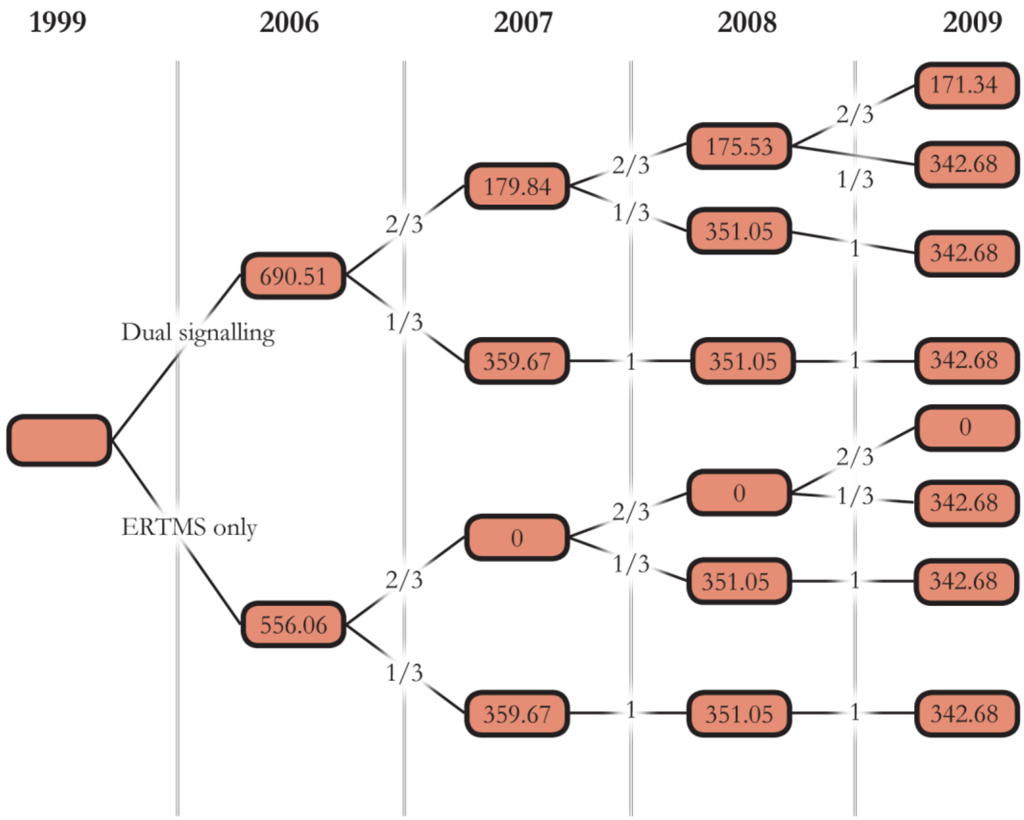

Figure 3: lattice showing discounted annual cashflows and probabilities; total NPV shown in 2006 nodes

It is apparent that the *Dual Signalling* version has a substantially higher NPV (in 2006 euros discounted back to 1999, the time when the decision not to install ATB was taken). Hence, the value of the ATB "option" is the difference between present values, in this case **€ 134.45 million**. As the *cost* of installing ATB has not been reckoned with in the analysis thus far, this means that it should not exceed this NPV difference for dual signalling to remain profitable (no estimates for the marginal outlay required for ATB signalling have been found in publicly available documents).

The analysis above is arguably simplified and stylized. For one, the ATB system is assumed to be worthless after 2009 (it has use nor salvage value), ERTMS is assumed never to break down, probabilities are fixed at an arbitrary level and the "benefits" of no service at all are zero, which is in itself debatable, while the benefits of an ATB-compliant service are likewise estimated to be half of those of a full ERTMS-based system. Methodologically, like in the OEI example, the probabilities and discount rates are unadjusted – according to theory (e.g. Mun (2006) and Trigeorgis (1995)) risk-neutral probability and discounting should be employed.

Nonetheless, adjusting the analysis to account for these deficiencies will reduce (or, in some cases, expand) option value, not eliminate it.

5.2 Statistics and risk analysis

Notoriously absent from OEI-compliant project appraisal is the practice of assessing risk based on probabilities and correlations: the prevalent methods of scenario and sensitivity analysis do not account for either the *possibility* that a certain scenario or variable change actually occurs or the effect that this might have on other variables or factors of relevance to project value (Belli, Anderson, Barnum, Dixon, & Tan, 2001). Hence, relying solely on these methods unduly places the burden of assessing probability not on the appraiser, but on the reader of the CBA, who is likely to be ill-equipped for this task. In this subsection we will succinctly offer four suggestions to address this.

5.2.1 Proper use of the risk premium

As described in Chapter 4, the OEI practice shifted from applying a uniform risk-free discount rate based on government bonds to a composite rate of a risk premium added to a newly-lowered risk-free rate. This closely mirrors the Capital Asset Pricing Model commonly used in financial economics, in which a project- or asset-specific beta coefficient is used to scale the risk premium added to the risk-free rate. However, an examination of Dutch cost-benefit analysis conducted pursuant to the *OEI Leidraad* reveals that all use a 5.5% discount rate, equivalent to a beta of 1. Given the vastly different nature and scale of the projects under consideration – from a sea access lock to a comprehensive regional development project – this assumption is most likely to be highly inaccurate. Hence, it stands to reason that an effort should be made to establish an estimate of project-specific beta, lest risky projects be overvalued and possibly admitted wrongly (or the converse). The methods described in Addendum 6 to the *Leidraad*, cited in Chapter 4, may be of use here: statistical analysis, stochastic simulation or previous experience.

Considering CAPM was developed to value stocks traded in a "deep" public market, it is decidedly impossible to use common financial economics methods for coefficient estimation, generally regressing stock returns on those of "the market". Not only is there no market where infrastructure projects are traded, the underlying assumption of investor diversification arguably do not hold in the case of transport infrastructure. This does not mean that no beta coefficient estimate can be provided, rather, that the process of its estimation is less clear-cut and accurate than for publicly traded company stocks. Addendum 6 offers a pragmatic solution: establishing the covariance between (forecast) net project benefits (a proxy for returns) and (forecast) GDP growth (a measure of market returns). In our opinion, this may also be conducted for a previous project; the beta thus established may be used as a 'yardstick' to compare the current project to: is it riskier or less risky?

Even a measure of qualitative guidance is likely to yield better results than the current method of deeming all projects of equal risk, exactly correlated to GDP growth.

An alternative is to employ stochastic (e.g. Monte Carlo) simulation to establish this relationship: while this has no empirical bearing, and requires that the distributions of relevant variables be input, it has the advantage of calculating all possible "paths" of GDP and project development, while using historical data allows only one path to be considered. Naturally, the required distributions (for instance, of construction cost and time) may be sourced from previous experience, as argued by Ye and Tiong (2000).

5.2.2 Broader use of scenario analysis

The guideline's authors state explicitly in Addendum 6 the need for risk-through-discounting (see previous paragraph) and 'conventional' methods to coexist for the foreseeable future. The known shortcomings of sensitivity analysis can in part be addressed through sensible scenario analysis, where several key variables take on different, but probable levels in concert. Arguably, a sound scenario based on expert analysis or historical experience is a step up from haphazardly changing key variables one at a time; therefore, we reason that scenario analysis is a possible area of improvement in OEI-based cost-benefit analysis. Of the 24 Dutch CBAs analysed in Chapter 4, thirteen used some form of scenario analysis. Most often, the scenarios employed were of a macroeconomic nature, in line with the explicit recommendations in the *Leidraad* and its addenda. However, a small number used project-specific "microscenarios", in which key variables are directly affected by certain relevant developments. This practice is amply demonstrated in (Belli, Anderson, Barnum, Dixon, & Tan, 2001) and (European Commission, 2008) to be a quick, comprehensible method to show project effects. Hence, a greater use of scenario analysis – with a more detailed description of what these scenarios entail, and how they are expected to come about – is expected to aid risk appraisal in the Dutch case, in a way that is instantly understood by stakeholders and policymakers. The use of scenario analysis may even encompass different project options or levels of implementation, as recommended by the European Commission in its 2008 guideline.

5.2.3 Rationalize sensitivity analysis

Tying in with the supposed ongoing preponderance of conventional risk analysis method, it bears to improve the quality and transparency of sensitivity analyses employed in cost-benefit analysis. A cursory analysis of Dutch transport CBAs (summarized in Chapter 4) revealed not only the popularity of this method, but also a wide variation in the variables subjected to sensitivity analysis. While the guideline calls for at least the discount rate to be included in a sensitivity analysis, this only occurs in a minority of cases, as Table 3 shows. Furthermore, the mechanisms by which these critical variables are selected remains largely opaque to readers of the CBA report; the criterion, set by the European Commission, of *"an absolute variation of 1% around the best* *estimategives rise to a corresponding variation of not less than 1% [...] in the NPV"* (2008), in other words, unity elasticity, is not heeded. Disclosing the process of and motivation for variable selection would aid transparency and allow for a critical appraisal of the risk management process, while a uniform selection of variable types would make possible a "quick and dirty" comparison of sensitivity and risk across projects. Finally, including a measure of the statistical likelihood of the stipulated amount of change actually occurring would serve to address one of sensitivity analysis' known shortcomings; if the distribution of the variable is known, this is but a trivial calculation. At any rate, the appraiser is better poised to endeavour such an estimate, a task that is hitherto left to the reader.

5.2.4 Calculate NPV distribution using Monte Carlo Simulation

As recognized earlier in this paper, Monte Carlo simulation is a powerful tool to address the common deficiencies in conventional risk appraisal, such as the disregard for correlations and probabilities, as well as the "false certitude" conferred by a single project value. The NPV-at-Risk and Quantitative Risk Analysis methods covered in Chapter 2 demonstrate how Monte Carlo Simulation might be used in valuing infrastructure projects in a fashion that results in a "band" of possible project values along with a set of meaningful statistics, such as the probability of profitable operation. Furthermore, Monte Carlo simulation provides some of the inputs necessary for other risk management techniques, such as Real Option Valuation (see section 5.1) and risk premium (see section 5.2.1). At present, only a single OEI-compliant CBA used such an analysis (Centraal Planbureau, 2011), noting its novelty and extra effort required, but also its great impact on the report's conclusions. Obviously, determining the distributional qualities of the variables involved requires effort that would otherwise not be expended; the feasibility of this endeavour is nonetheless accentuated and demonstrated by the European Commission (2008) and (Belli, Anderson, Barnum, Dixon, & Tan, 2001).

5.3 Chapter conclusion

The combined areas of transport economics and financial economics offer a host of possible improvements over the current risk management practice in the *OEI Leidraad*, some of which are minor (such as improving scenario and sensitivity analysis) while others constitute a sizable paradigm shift in how risk is regarded (i.e. real options valuation). Given the high degree of uncertainty inherent in the act of project appraisal, regulators, policymakers and stakeholders should be wary of accepting any cost-benefit analysis that provides just a single figure for project value. While the OEI framework requires that risk analysis take place, too often it is regarded by appraisers as an annex to the analysis and conducted in a manner that is lacklustre and not uniform across projects. It should be noted that this constitutes an improvement over pre-OEI practices nonetheless; the original HSL-Zuid cost-benefit analysis did not include any quantification of risks (Tweede Kamer der Staten-Generaal, 2004).

Conclusion

This research revealed how, in spite of their disjoint nature – with very little overlap of research – financial economics and transport economics show remarkable overlap in some areas. While the philosophical underpinnings of each, such as the "goal" of project appraisal, are different, as is the exact nature of "costs" and "benefits", both employ similar methods to tally and value cost/benefit streams.This overlap is obfuscated by these conceptual differences and the very different nature of research context – financial project appraisal takes place almost exclusively in an environment where private involvement is at play, whereas "traditional" appraisal based on welfare economics presupposes exclusive involvement of the state and its actors. In spite of this chasm, a gradual convergence and exchange of methodologies appears to be ongoing, as shown by the increased interest in accurate risk modelling in transport project appraisal. In other words, the generally disjoint nature of the fields belies their shared provenance and ongoing integration.

The Dutch appraisal practice, laid down in the *OEI Leidraad*, evinces a predisposition towards "traditional" welfare economics. It is notably light on financial evaluation of projects, somewhat in contrast to European practice. Unfortunately, it is vague in parts, preferring not to lay down overly strict guidelines for valuing, for instance, environmental effects. In some areas – such as that of social discount rate, and travel time appraisal – it contravenes starkly the methods and notions espoused in most research. Plus, adding to the muddle, cost-benefit analyses in The Netherlands are at times revised, subjected to 'second opinions', or even ignored.

Having analysed the main tenets and key specific factors of valuing (transport) infrastructure, financially and from the viewpoint of public welfare economics, we now turn ourselves to identifying and summarising the different approaches in a number of key areas. Only those factors with a stark apparent contrast are included – demand estimation, for instance, has been left out for want of a clear framework in either field, and a resulting lack of contrast.

	Financial analysis	Welfare economics	*OEI Leidraad*
Cost / benefit components	Cashflows	Social welfare effects	Social welfare effects
Compared to	Zero *or* risk-free investment	Zero	"Viable" alternative
Valuation methodologies	NPV, IRR, Real Options	NPV, IRR, B/C-ratio	NPV
Risk analysis / mitigation	Mean-variance analysis, Value-at-Risk, Monte Carlo simulation, hedging	Sensitivity analysis, switching analysis, Monte Carlo simulation (rarely)	Sensitivity analysis, scenario analysis
Effects valued	Direct & charged only	Direct, Indirect, External	Direct, Indirect, External (only in "full" *MKBA*)
Time horizon, rationale	Investment lifetime (years before exit)	Economic lifetime (minus environmental factors)	"Not too long" depending on discount rate
Time horizon, actual values	5 – 10 years	25 – 30 years	~27 years (>50 years in addenda)
Discount rate, rationale	Account for time value plus risk (non-diversifiable), sometimes inflation & liquidity	"Social discount rate" – risk-free rate, govt. borrowing, **or** zero/declining (environmental equity)	Risk-free rate (before 2007), risk-free rate plus project-risk markup
Discount rate, values	4% - 20%	0% - 8%	4% and 5.5%
Environmental effects	Only if taxed	WTP[1]-based: revealed and stated preference	WTP-based; preferably revealed preference
Time savings	No (though may allow for higher charges)	Based on opportunity cost, tiered[2]	Based on questionnaire, tiered, extrapolated
Accident prevention	Not included	Output method; WTP-based (stated or revealed)	No guidelines

1 = Willingness To Pay; 2 = split by income, modality and purpose of trip

Table 4: Overview of key differences between infrastructure valuation from the financial, welfare economics and OEI perspective

The authors of the *OEI Leidraad* themselves appear to recognize the often lacklustre level of risk evaluation and mitigation in transport infrastructure appraisal; a view that is echoed in transport economics literature and in EU documents. Compared to the private sector, where the field of financial economics has given rise to a multitude of techniques to this end, the dominant methods – scenario, sensitivity and switching analysis – have notorious shortcomings. We believe that addressing this deficiency using cutting-edge modelling techniques – such as Real Options Valuation and Monte Carlo Simulation – would improve project appraisal accuracy at very little cost, aiding social welfare as a whole and making project management more robust.

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