

Real Options applied to infrastructure projects: a new approach to value and manage risk and flexibility

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Abstract—Infrastructure projects are subject to internal and external uncertainties. Being able to anticipate to uncertainties within a project and manage them adds value to the business case. Although it is commonly used to evaluate projects, the Net Present Value (NPV) method is unable to determine the added value of managing risk and flexibility. Real Options (RO), a method originating from financial markets, gives management a tool to value flexibility and risk in infrastructure projects. Literature provides several examples on how to value options or execute a Real Options analysis. However, the majority of these examples fails to incorporate all opportunities offered by RO to include options and/or ways to reduce uncertainty.

This paper presents twelve opportunities that should be considered to minimise the risk of a project and increase the flexibility of the project during its lifetime. This checklist is based on practical experience with project evaluations and could be used as a starting point to list alternatives that should be evaluated. Including a wider set of alternatives in an evaluation has substantial benefits and may lead to different decisions.

I. INTRODUCTION

GOVERNMENT and industry face important strategic decisions that become increasingly more complex and difficult due to the uncertain circumstances under which these decisions are taken and the financial ramifications they may have. Examples of these decisions include investment decisions in new airports, roads or production plants. Those in favour of an investment or a project tend to neglect uncertainties, while opponents stress the adherent risks resulting from uncertainties in demand, cost or technology development. As a result, it is difficult to make a firm and broadly accepted decision. Large infrastructure project decisions are subject to uncertainty by definition since the development period from initial idea to actual use of new infrastructures may take years or even decades. During this period, the demand forecasts or requirements are likely to change.

Although awareness that the impact of risks associated with these decisions should be incorporated in decision-making is growing, the use of proper tools to take these inherent uncertainties into account is rare. In general, the Dutch government and the private sector use a traditional method to evaluate uncertain business cases: the Net Present Value method (NPV). This method however, has two major drawbacks.

For one, it uses a constant discount factor to translate future cash flows into present value accounting for price inflation and for risk of disappointing returns or costs during the course of the project or payback period. Typically the discount factor is set by the corporate treasury or Treasury, therefore has a generic character and does not account for project- or alternative- specific risks. For instance, a NPV-analysis usually does not differentiate between discount rates of a new bus line estimated to cost exactly 2 million and a line estimated to cost between 1 and 3 million with an expected value of 2 million. Consequently, the uncertainty in the second alternative is not appreciated and both alternatives have the same value. Furthermore, using a constant factor implies no differences in uncertainty of costs and benefits at the start of a project versus those at the end of the project, which is unlikely.

A second drawback is that NPV neglects the occurrence of minimum or maximum scenarios throughout a project's (development) life time and the effects strategic management decisions may have in these scenarios. For instance, in certain scenarios a project may benefit from being temporarily put on hold or to phase, accelerate, decelerate, or even abandon the project at a certain moment. Also changing the strategy based on new information, may improve a project's feasibility. NPV ignores these options and relies heavily on averages or expected values. Using NPV for projects that have a long life span or that are subject to a high level of uncertainty may lead to incorrect cash flow and project value predictions, which partly takes away the basis for informed strategic decision-making.

This paper presents a method that addresses these drawbacks: the Real Options method (RO method) and a checklist listing the possible options and project choices to evaluate. The paper starts with a discussion of Real Options and the advantages of this method compared to the more commonly used Net Present Value method, demonstrated in a simple example. It continues to give twelve examples to

Manuscript submitted on 15 April 2008.

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reduce uncertainty or make a project less risky by building in options. These examples are based on practical experience with project evaluation and can be used as a checklist or starting point to list the alternatives that should be evaluated in a real options evaluation. Finally, some general conclusions are drawn.

II. REAL OPTIONS

Compared to NPV, Real Options is a more flexible method to value projects, which addresses the concerns mentioned above. The method originates from financial markets, where financial options are financial instruments on assets that convey the right, but not the obligation, to engage in a future transaction. An option gives someone the right to buy or sell for instance stock at a predetermined point in time at a predetermined price. Options are valued based on the Black-Scholes model, for which Merton and Scholes received the Noble Prize in 1997. The value of options reflects the stock's expected value development including any uncertainties that surround this expectation. In other words, the value of financial options can be seen as the price you pay to buy-off uncertainty and buy flexibility.

Real Options applies the same method for the valuation of options / choices in projects and investments. The risk of disappointing project costs or investment returns are the Real Options equivalents of the risk of fall in prices from financial markets. Similar to financial options, Real Options enables incorporating differences in risks and flexibility in decision-making in a more sophisticated and objective way compared to NPV.

In Real Options, the options are predefined choices along a project's time span that strategically, tactically or operationally affect the course of the project. Since Real Options is a technique to manage risks before and during the project, it defines decision points at which these choices are made. These points can be points that are fixed in time, points that are fixed in the project process, or that are triggered by project external variables, such as global oil prices or currency exchange rates. Section IV discusses the twelve opportunities we distinguish between and that can be valued using Real Options.

After the opportunities have been identified, Real Options may be used to value the options and differences in risk. For this purpose the method values expected future cash flows according to their associated risk. If the outcome of an investment or project is uncertain, cash flows will have a wide range of possible outcomes for which reason risk is high. The variance of the expected project result is used as a correction factor in the business case to compensate for riskiness. As a result, cash flows in risky projects are corrected downward and thus lower than in more certain / less risky projects. RO enables a more detailed way to value

project risks.

In addition, Real Options offers the opportunity to value a wide variety of scenarios. Different management decision points can be built in to anticipate to scenarios that may develop over time. This allows adjusting a project's course during its lifetime if new developments give rise to such a decision, thus introducing flexibility. These decision points are depicted in a kind of roadmap with specific critical variables informing management to adjust decisions (signposting). The outcome of these decisions affects the value of the project and should be considered in the valuation of the project before deciding to kick-off. If critical variables reach predefined trigger values alternative approaches become more profitable. For example, the world oil price may be a deciding factor to develop a hydrogen car.

In addition to the advantages of incorporating risk and flexibility, the decision tree that underlies RO helps to better understand the project and generates added value itself. It structures and makes uncertainties, variances and management decisions explicit throughout the project. It also urges a company's management to think about which risks they are willing to accept, which alternatives they should consider and how risks can be managed in an (cost-)effective way. This means management needs to decide whether fail-safes need to be built in at certain costs anticipating to potential future developments.

Although Real Options is more complicated and therefore more costly to apply in decision-making than the standard Net Present Value method, in many projects this burden is well offset against the benefits of valuing flexibility and uncertainty (see Table 1 for characteristics).

RO has more added value	NPV suffices
Decisions affect long timeframes	A project has a short timeframe
Volatility or uncertainty of the costs/revenues is large	There is a small bandwidth of possible outcomes
The benefits to the project's business case outweigh the costs of introducing options	Options have no added value
Information that affects the project's benefits / costs becomes available during project lifetime	No new information becomes available during project life
Project benefits / costs are susceptible to external trends and developments	In each condition the same decision will be made

Table 1 – Characteristics of projects that benefit most from RO

III. EXAMPLE

We will illustrate the benefits of the RO method compared to the NPV method using the option to phase in an example of the 'Zuiderzeelijn' project. The Zuiderzeelijn was envisioned to be a new train connection from Schiphol Airport via Amsterdam to the northern part of the Netherlands. The aim

of the project was to reduce travel times to and from the northern part of the Netherlands and improve the economic development of the Netherlands in general and the northern part in particular. Over the past decades, several studies, based on the NPV method, indicated that the estimated project costs would be too high. For this reason the Dutch government decided against the Zuiderzeelijn. The figures shown in the example are merely illustrative and do not represent actual facts from the Zuiderzeelijn-study.

Using the NPV method to value the Zuiderzeelijn assumes the full connection (i.e. from Schiphol to Groningen; a city in the northern part of the Netherlands) is equipped as a Maglev track. The RO method offers the option to phase the project by building the part from Schiphol to Almere (a suburb from Amsterdam) first and only build the second part from Almere to Groningen if the expected number of passenger kilometres reaches a specified threshold. In case the forecasted number of passengers deviates from actual numbers in the future, the strategy can be adapted. Having this flexibility to cancel or postpone construction of the second part of the connection may save costs.

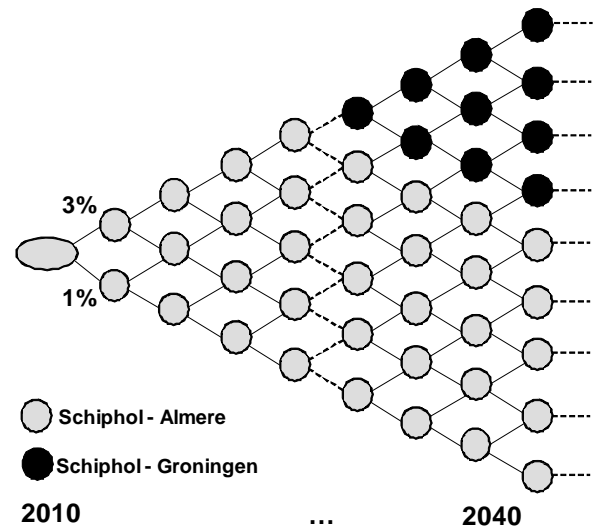
In this example, the inputs for the NPV and RO method are given in Table 2. In each year from 2010 to 2040, there is an independent probability of 50% to have a growth of 1% in passenger kilometres and a 50% probability of 3% growth. After 2040, the number of passengers will remain constant. The investment costs recur every 30 years and the Zuiderzeelijn will serve passengers indefinitely. We assume that the costs of building the Maglev track in one go are 10% lower than if the project is built in phases. The profit of 8 Eurocents per kilometre reflects the margin between the train ticket prices and costs of maintenance, operating, etc.

Costs (in million Euro)	
Schiphol – Almere	2500
Almere – Groningen	5000
Schiphol - Groningen	6750
Passenger kilometres (in millions)	
Schiphol – Almere in 2010	900
Almere – Groningen in 2010	1050
Schiphol - Groningen in 2010	1950
Annual growth passenger kilometres low	1%
Annual growth passenger kilometres high	3%
Profit per passenger kilometre (in Euro)	0.08

Table 2 – Inputs for the NPV and RO method

If the project from Schiphol to Groningen is built in one go, the Net Present Value of the project is approximately -130 million Euro, which would lead to the conclusion that investing in the Zuiderzeelijn is not profitable. The option to phase gives us the flexibility to decide each year whether to build the second part of the Zuiderzeelijn from Almere to Groningen depending on the annual growth rate, or not. If the

annual growth in passenger kilometres remains high for several consecutive years, the part from Almere to Groningen becomes profitable. The figure below illustrates the circumstances under which it is more profitable to build only the part from Schiphol to Almere (grey dots) and in which cases the opening of the second part becomes profitable as well (black dots). The option to phase gives decision-makers the possibility to anticipate on future development, in this example the growth in annual passenger kilometres.



As demonstrated before, the economic value of the project using the NPV method is negative. If we value the project with the RO method and use the option to phase, the project is valued at about 1.050 million Euro. As a result, the option to phase has a value of approximately 1.180 million Euro (see Table 3).

Value project Zuiderzeelijn (in million Euro)	
NPV method: Schiphol-Groningen	- 130
RO: phased approach	
Standard Schiphol-Almere	+ 1.050
Optional Almere-Groningen	
Value option	+ 1.180

Table 3 – Results for the NPV and RO method

As can be seen from this example, the benefits of this project can differ substantially between the two methods and decisions based on the NPV method could well be suboptimal.

In the Netherlands, the use of Real Options is in its infancy, in spite of the benefits and the confirmed need by policy makers of the Dutch Ministry of Transport, Public Works and Water Management makers^[5]. To help policymakers evaluate all the possibilities to reduce uncertainty and risk of a project and make Real Options more accessible, we present twelve opportunities that can be valued with RO and illustrate them with examples in the next section.

IV. CHECKLIST

Since project risks lower a project's value, introducing opportunities that limit risk represent additional value. A carefully selected set of opportunities can turn an inherently risky project into a low-risk project. To assist decision-makers in considering all opportunities that can reduce project risk and thus add value to a project, we compiled a checklist of twelve ways to reduce uncertainty and risk that should be considered. RO can be used to select the most attractive opportunities based on the difference in value between each alternative. For detailed calculation the reader is referred to the literature on real options^{[1][2][4][6]}. In some cases a qualitative evaluation of these options and project choices suffices to adjust and improve a decision.

In this section, we discuss these twelve ways to reduce uncertainty and risk. Within the checklist, a distinction can be made between: 1) project opportunities that limit the variance within a project and hedge against uncertainty before the project start, and 2) options that give management the flexibility to influence the project during its lifetime.

To illustrate these opportunities we will use the Zuiderzeelijn project where applicable or general examples.

Ila. Project opportunities to reduce uncertainty

The first opportunity is the possibility **to influence** the outcome of a project **or shape** the determining parameters. For instance, if achieving a project's objective requires support from different stakeholders, considering changing the project organisation to include these stakeholders (e.g. by setting up a public-private partnership) may deliver the required support and reduce the uncertainty. In another example, in case we strive to reduce the number of traffic casualties, the speed limit on a highway could be lowered to reduce the number of accidents on that highway. Alternatively teaming up with one of the competitors in developing new technology reduces chances that a new technical standard will be owned by the competition. In the Zuiderzeelijn project this possibility is used by the consortia where the power of several companies is combined in a joint effort to try to convince stakeholders and decision-makers.

Another opportunity is **to spread or distribute** the risks within a project. Outsourcing project tasks to another company that is better equipped to perform those tasks and fixing the associated costs, lowers the overall project risk. The purpose of this opportunity to spread is to reduce the uncertainty of (parts of) the project. For governments requesting fixed prices and developing design, build, finance, maintain contracts (DBFM contracts) with industry is an example of the opportunity to spread or distribute risks.

The third opportunity refers to the option **to investigate or learn**^[1]. Investing in additional research before the project start leads to more and better information. The research

outcome may be that the project is not worth starting at all, for example extra test drills in a new oil field may indicate that a certain location is not feasible to explore. Planning of maintenance of highways or arterial roads can be improved if the government performs additional research on their current state. Detailed research into passenger demand is an example applicable to the Zuiderzeelijn project.

If during its lifetime a project highly depends on for instance, Dollar and Euro exchange rates, it is possible to buy options on the financial market that guarantee the exchange rate throughout the project. This opportunity **to insure or hedge** leads to higher initial costs, but reduces the risks of the project. For contractors a low number of workable days due to weather conditions can impact project success and can be insured against.

In trading stocks on the financial market, one way to reduce risks is to have a portfolio of stocks instead of stocks from a single company. The same argument holds for Real Options. A portfolio of infrastructure projects has an overall lower risk, than the sum of individual projects. This opportunity is called the opportunity **to diversify**. A number of different projects all aimed at solving the mobility problem in the Netherlands is less risky than each project separately.

The sixth opportunity is the option **to exit or abandon**^{[1][2][4][6]}. Terminating a project at some stage can be more cost efficient than continuing it until the end of its lifetime. Terminating clauses can be put into contracts to have this kind of flexibility. Other examples are the closure of roads or cost inefficient transit lines. Demand (e.g. the number of predicted passengers or number of predicted cars) is an important variable in a transport study business case. In a public private partnership, a toll road will only be built if the business case forecasts a positive cash flow. The option to exit, if predictions change downward in an early phase of the project, can have a significant value.

Ilb. Project opportunities to increase flexibility

The Zuiderzeelijn was initially intended to be a Maglev, which costs are higher than the costs of a conventional train. These higher costs should be offset against the Maglev's innovative character and higher speed of up to 400 km/h. Building in the flexibility of making the final choice between Maglev and conventional train at a later stage, allows future (technological) development to improve the business case for either of the two alternatives. The option **to switch**^{[1][2][4][6]} between Maglev and a conventional train is only possible when the same footprint is kept available to build the connection.

Other options to switch can be seen in for instance power plants, in case a plant is capable of burning oil as well as coal or biomass anticipating on current price levels. Although building in flexibility to switch often leads to higher initial

costs, the added value of flexibility can be high.

The number of Maglev trains in the initial purchase order depends on the number of expected passengers that use the Zuiderzeelijn in the future; one of the reasons for which demand is an important factor as mentioned above. As time passes, the predictions of the number of passenger become more accurate. Translating this information into flexibility options, the number of Maglev trains on order can be kept at a relative low level during the early stages of the project. Extending the order at a later stage can be built into the business case by an option **to grow or to expand**^{[1][2][4][6]}. Although increasing the number of Maglev trains on order is easy compared to expanding road capacity, the option to grow is being put to practice implicitly in the construction of new highways in the Netherlands. If future traffic demand is expected to exceed road capacity, additional space is reserved to add an additional lane in the future. Growth options can also be evaluated with regard to the company or organisation involved in the project instead of the project itself (a corporate growth option). In this case the question of whether participation in the project will provide knowledge, experiences or market access that has spin-off value for other (potential) projects is relevant. For instance, successful operation of Maglev trains on the Zuiderzeelijn can reduce the risks of other Maglev projects.

The **option to accelerate or decelerate** within the Zuiderzeelijn project is the opportunity to reduce or extend the development and construction time of the project. In case for instance the project is behind on schedule, people can work 24 hours a day to catch up.

The ability of oil production companies to align oil production with the changing demand for oil and world oil prices is an example from the oil and gas industry of how flexibility can add value to a project.

If the Zuiderzeelijn would have been developed, constructing the connection would have taken more than a decade. In case of a conventional railroad, several companies would be able to deliver the required trains within this period. Postponing the selection of the manufacturing company for the trains introduces flexibility to, for instance, better align orders with future demand and adds value to the project. While the decision with regard to the numbers of trains to order is on hold, uncertainties reduce. This is referred to as an **option to delay or defer**^{[1][2][6]}.

Option/opportunity	Questions to ask	Example
To influence or shape uncertainty	Have you evaluated the opportunities to limit uncertainty by forming alliances or influence one of the parameters that determine the variance of the output and make the project less risky? Did you consider investing in pre-empting competition?	Weight limit trucks to reduce uncertainty in road deterioration
To spread or distribute risks	Did you consider all possibilities to divide the risks over the parties involved and assign tasks to those that are most capable to manage the risks?	Negotiate fixed price contract with road construction company
To investigate/learn	Did you evaluate opportunities to develop knowledge or get more information on the uncertainties?	Try test sections for their maintenance characteristics
To insure/hedge	Did you evaluate opportunities to insure or hedge against some of the risks?	Insure for currency exchange-rate variation or maximum number of non-workable days
To diversify	Did you consider the possibility to combine projects with a different risk profile to limit the overall risk?	Combine different approaches to reduce traffic jams: road information, better public transport, more capacity roads
To exit/abandon	Have you accounted for the fact that the project can be abandoned after the start and a salvage value can be collected?	Stop maintaining infrastructure if more cost efficient alternatives are available

Table 4a – Checklist overview opportunities to reduce uncertainty

Option/opportunity	Questions to ask	Example
To switch technology, markets, products	Have you considered the opportunity to change inputs (use of material), outputs (products and markets) and used technology during operation to improve the business case?	Switch between conventional trains and Maglev on Zuiderzeelijn
To grow (project or corporate growth)	Have you considered benefiting from new opportunities afforded by new technology developments, market access, knowledge and experience gained during this investment project? Have you accounted for the fact that exercising one option can open up new options?	Reserve space for additional lanes; Use developed technology in other projects/markets
To accelerate/ decelerate	Have you considered the opportunity to balance resources and time and adjust the building time or roll-out time to limit risks?	Adjust tempi of river dike adjustments based on sea level developments, rain fall and flooding risks
To delay	Have you considered delaying the decision until more information becomes available or the conditions to invest are improved? Is the value of deferring higher than investing now?	Delay procurement of trains until completion date of railroad is more certain
To phase	Have you considered the opportunity to divide a project or investment into separate investments that can be phased in time? Did you consider adjusting the definition of a consecutive phase based on the results of the previous one?	Depending on economic development and need for space a new area (Maasvlakte) is developed in phases
To scale	Have you considered the opportunity to adjust the production capacity both upward as downward (temporarily)?	Allow temporary peak hour lanes

Table 4b – Checklist overview opportunities to increase flexibility

The Maglev solution for the Zuiderzeelijn project is

expensive. Based on passenger forecasts the business case for the part from Schiphol Airport to Almere is more likely to be feasible than the part from Almere to the northern part of the Netherlands as illustrated in section III. The option **to phase**^[6] this project by first constructing the part from Schiphol Airport to Almere and consider the connection to the northern part as an option adds value to the business case. This option is also known as the Time-to-Build option^[6].

Providing service on the Zuiderzeelijn with two Maglev carriages in peak hours and only one Maglev carriage during off peak hours saves operating costs. This option **to scale**^{[2][6]} (also known as option to contract in case of shrinking) relative to the demand for transport leads to higher initial costs (more carriages), but to lower operating costs during off peak periods.

Currently, peak hour highway lanes are the most illustrative example of scaling. In this example, infrastructure capacity is increased during peak hours by opening an extra lane. For safety reasons, the speed limit is reduced during this period. Current road-design anticipates on opening an additional lane during peak hours by increasing the width of roads.

Tables 4a and 4b give an overview of the twelve opportunities and/or options that should be considered to limit the uncertainty and risk before and within a project and maximise the flexibility management has during the life time of a project. The third column illustrates these options/opportunities. Within a project several options/opportunities can be applied. Then the value of options and choices can be dependent on the outcome of other options (see compound options^[4] or sequential options^[2]).

V. CONCLUSION

Applying Real Options to make informed infrastructure decisions requires more effort than the traditional Net Present Value method. However, this additional effort is more than offset by the potential value it creates, risks it reduces and flexibility it increases. Furthermore, Real Options delivers additional insight, information and the project 'script' that can guide management in making well-informed and optimal decisions throughout the project life time.

Infrastructure decisions benefit from using the option checklist in tables 4a and 4b to make sure that a broad set of potential ways to limit project risks are considered. Simply considering an option qualitatively can be sufficient to improve the decision. For large infrastructure projects, the options that can substantially influence the outcome of a project should be evaluated in close detail.

Though infrastructure projects are often political decisions, the decision process typically involves intensive Cost-Benefit Analysis and Impact Assessments. Currently these practices make relatively little use of Real Options, in spite of references to RO in OEEI^[3]. Additionally, the need for evaluation methods with features similar to Real Options is confirmed by transport policymakers^[5].

With this paper and our checklist we hope to make the method more accessible to infrastructure policy makers and stimulate the use of this method. The checklist can be used as a guide to determine the opportunities of a project and improve decision-making by the valuation of the identified opportunities with Real Options. This is particularly true for infrastructure projects that are subject to many uncertainties and changing conditions between start and finalisation of the project. The economic viability of these projects could benefit from many of the identified opportunities to reduce the uncertainty and project risks.

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