**Building Options at Project Front-End Strategizing: The Power of Capital Design for Evolvability**

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**Manuscript Summary**

Capital projects are undertakings that invariably require massive investments, take many years to design and deliver, and produce outputs that are expected to operate for several decades. During project delivery and operational lifetime, the functional and operational requirements are likely to change. To make the project outputs economically adaptable to foreseeable change in the future, sizeable investments in design flexibility may be required upfront at front-end strategizing. Under uncertainty about the future and tight budgets, multi-stakeholder project teams must trade-off additional investments in design flexibility at risk they may not pay off if uncertainties resolve unfavourably in the future with more affordable investments in rigid designs at risk of costly adaptation if uncertainties resolve favourably in the future. How to help multi-stakeholder capital project teams bridge their divergences and coalesce their views of the world into a design for evolvability strategy at project front-end strategizing is the core motivation for this work.

After reviewing the limitations of current practice and theory in the management of capital projects, this study turns to real options reasoning and design literature. By definition, investments in design flexibility can be equated with buying options: if the future resolves favourably, the options can be exercised to adapt the design economically; otherwise, a limited investment has been lost. To advance theory and practice on capital design for evolvability, this study combines empirical research with experimental work. The empirical studies produce two insights: first, they reveal that project teams invariably use options thinking intuitively and that real options mathematical models are inadequate to support mundane design decisions at front-end strategizing. And second, the empirical studies show that the difficulties of designing for evolvability become amplified whenever multiple stakeholders are involved at front-end strategizing. Under sharp asymmetries in capabilities, knowledge, and power, multi-stakeholder teams must resort to negotiations intertwining informal options thinking with ‘money talks’ to resolve concept design. Tensions are likely to flare up whenever stakeholders demanding capital investments in design flexibility are not in a position to fund them. These findings suggest nonetheless a formal procedure to design for evolvability may offer a superior approach at front-end strategizing to help teams strike the right balance between short-term affordability and long-term adaptability, as well as to become more accountable for the decisions made at the front-end.

To test this proposition induced from the empirical studies, this research develops an original proof-of-principle of a formal framing to support early design decision-making when front-end strategizing capital projects - we call it *design for evolvability (dfE)*. This framing cross-fertilizes literature on project risk management and real options theory with empirical insights from the fieldwork. We also develop a two-group controlled experiment – grounded on fine-grained empirical data from a real-world railway station redevelopment project – to compare the performance of the experimental and control groups in terms of effectiveness, efficiency, and satisfaction. We assembled several teams of postgraduate students to conduct the experiment. About half of the teams were instructed to adopt the formal design for evolvability framing, and received aid of a champion who facilitated the process.

Comparative content and statistical analyses of the experiment deliverables, students’ reflection essays, responses to a questionnaire, and debriefing sessions indicate consistently that a reframed front-end strategizing process improves both the quality of the multilateral conversations substantiating mundane design decisions and the decisions themselves. Specifically, the teams who worked with a design for evolvability champion were systematically more efficient because they tended to find common ground faster than those in the control group. The experimental results suggest that a formal design for evolvability framing makes the team members more aware of the need to share information about their own view of the world in regards to future operating scenarios and funding issues. And as teams build common ground quicker, they become more efficient and have more time left to discuss which options should be designed in and how exactly to fund them. This in turn leads to front-end strategizing outcomes that are more effective in reconciling short-term affordability with long-term adaptability. In contrast, unaided teams are more likely to run out of time and to fail to hammer out a deal to fund design optionality even if they may agree on the need to design in the options. Importantly, our results do not show any statistically significant difference between the two groups regarding their overall sense of satisfaction with the front-end strategizing process. This suggests the teams did not push back on overlaying a formal framework to early design decision-making albeit the time pressure to resolve the front-end strategizing process.

Overall, this research recommends practitioners to adopt an options reasoning formal framing to support design decision-making at front-end strategizing. Our results suggest the superiority of this approach as it increases the quality of the outcomes and the project teams’ accountability for design flexibility decisions. The results do not advocate teams should outrightly endorse investments in flexibility. These investments need to be agreed in a multi-stakeholder context and balanced against affordability constraints. But the results show the importance of putting in place a formal decision-making process to ensure a proper debate precedes decisions to endorse or rule out design flexibility investments. An informal process increases the chances that the design flexibility debate – does not matter if inadvertently or not - drops off the agenda at front-end strategizing. And this can create unjustifiable risks that a rigid design moves forward under conditions of high uncertainty. And if costly changes then become required, the project costs must spiral and the project can get derailed. At the limit, failure to properly discuss design flexibility creates an unnecessary risk that a capital project delivers a rigid asset slated to become prematurely obsolete in its operational life. Design for evolvability is therefore essential to pre-empt a lack of intergenerational equity.

**Guilherme Biesek** and **Nuno Gil**, Manchester, December 2012

# Acknowledgements

This manuscript consolidates research carried on between September 2009 and December 2012 as part of the doctoral studies of Guilherme Biesek at the Manchester Business School (MBS) under the supervision of Professor Nuno Gil. This research was sponsored by a 2 ½-year external research grant awarded by the Project Management Institute in 2009 (recipient Nuno Gil) and a 3-year MBS PhD bursary (recipient Guilherme Biesek). Its industrial sponsor was Network Rail, the private company but limited by a public guarantee that owns and operates Britain’s railway infrastructure.

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# Introduction

## Problem Articulation

The design and development of new large-scale infrastructure assets is a fundamental project-based undertaking through which private and public organisations can create value. Physical infrastructure such as airports, railway lines, bridges, factories, hospitals, or power stations are main components (or systems) of critical and large socio-technical systems (or systems of systems) in transport, manufacturing, healthcare, and energy (Hughes, 1987). New infrastructure development (capital) projects play an important role in ensuring that existing socio-technical systems can respond to increasing demand for new services, evolution in usage patterns, and changes in technology. Capital development is also fundamental to ensure the broader socio-technical systems can cope with population increase, deterioration and obsolescence of existing infrastructure, migration flows towards cities, and the globalization of supply chains (Gil, 2009a). They are also advocated by Keynesian economists as one ‘road to recovery’ in times of an economic downturn. And according to this school of thought, capital investment in large-scale infrastructure projects contributes to the development of national economies by providing temporary and permanent employment, stimulating further investments, and promoting growth and development for local businesses. By the same token, the failure in delivering large-scale infrastructure projects effectively and efficiently can have enormous detrimental impact, both in the medium and in the long term, on the economy of whole nations given the physical and economic scale of these projects (Flyvbjerg, Bruzelius, & Rothengatter, 2003).

A major challenge in capital development projects is the need to design and build new assets that can adapt economically to evolving requirements over long periods. Infrastructure assets may take many years to negotiate planning consent, design, and deliver. They are also invariably designed to operate for several decades – the construction of some railway stations in the UK, for instance, dates back to the middle of the 19th century. However, during a prolonged project delivery and service lifetime the external environment will almost certainly evolve: new technology may emerge, user requirements and operating conditions may change, and new regulations may be introduced. These externalities can trigger developments in functional and operational requirements, which need to be accommodated through design changes. The cost of adaptation will then be a function of the flexibility built in the design of the asset.

Design definitions that are flexible to economically accommodate foreseeable changes in requirements in the future may need additional capital investment upfront to create modular architectures (Baldwin & Clark, 2000) or to safeguard integral architectures (Gil, 2007). From a life-cycle perspective, this additional capital investment to make the asset definition more flexible may pay off if the foreseeable uncertainties resolve favourably in the future. However, in situations where capital resources are scarce, requests for additional investment at the design definition phase cannot be taken as a given. By definition, large-scale infrastructure projects require large capital sums. Their design definition also takes many years to be negotiated amongst a large number of stakeholders. Any business case for an additional investment in a flexible design solution (which will only pay off if uncertainties resolve favourably in the future) will have to compete with other business cases for more immediate needs. Making a compelling case to invest in design flexibility at the project front-end can therefore be a challenge for public agencies operating under tight budgets and struggling to fund projects all deemed urgent. Scarcity of capital resources can also be a problem faced by private developers of infrastructure as they invariably operate under commercial pressures to achieve profits in relatively short timescales.

Failure to make upfront investments in flexibility can nonetheless compromise the ability of the assets to cope economically with foreseeable change. Early design decision-making in new capital projects therefore requires balancing decisions to make long-term investments in design flexibility (in order to mitigate the downside risk of costly changes in the future) with investments in rigid designs (at the downside risk that adaptation costs will be high if uncertainties resolve favourably). Put differently, capital investments in flexibility at the front-end ensure the project can deliver an effective outcome in that it has the capability to respond with reasonable economic costs to potential changes in the environment over its lifetime.

The problem of balancing upfront investments in design flexibility with decisions not to invest at risk but that expediently reduce costs in the short-term is compounded by the need to collectively negotiate these decisions. The number of project stakeholders involved in negotiations to firm up the design can be vast and includes project sponsors (the ultimate client such as a government or a corporation), the project client (typically an agent appointed by the sponsor and often termed the ‘client’ from a project suppliers’ perspective); future operators, suppliers; and other relevant stakeholders such as local communities, local authorities, and other public agencies. The claims of these stakeholders over the design definition may exhibit different levels of legitimacy (Gil & Tether, 2011), as well as conflicting priorities, and perceptions of risk (Gil, Miozzo, & Massini, 2012). Despite the autonomy of each stakeholder organisation, all organisations may share the ultimate project goal, a phenomenon observed not only in project-based undertakings but also in contemporaneous business ecosystems (Baldwin, 2012). Some stakeholders, however, may advocate design solutions that maximize their individual short-term gains, as opposed to be driven to maximise the shared value that the project can create to the whole. Empirical studies for example suggest that often project sponsors might endorse potential underperforming projects as long as they do not carry the risks themselves and are not accountable for performance failures (Flyvbjerg et al., 2003).

In summary, early design decision-making in large-scale infrastructure projects is invariably the outcome of multilateral negotiations that require factoring in a number of stakeholder perspectives on the costs and risks of design flexibility. Each stakeholder’s perspective will be shaped by: 1. different perceptions that foreseeable uncertainties will resolve favourably in the future; 2. the perceived costs of the design adaptation if uncertainties indeed resolve favourably; 3. the appetite to take calculated up- and downside risks; 4. affordability constraints and the stakeholders’ wherewithal to fund investments in flexibility; and 5. A stakeholders’ sense of entitlement to ask another organisation to incur the design flexibility costs.

Some stakeholders, particularly cash-strapped ones, may be reluctant to commit capital towards investments in flexibility that may take decades to pay off or that in some circumstances might not even pay off at all (Gil & Tether, 2011; Gil, 2007). Unless another party agrees to fund the costs of built-in flexibility at risk, these stakeholders may be willing to incur the downside risk of costly changes in the future at the expenses of creating an issue of intergenerational equity. A lack of incentives to invest in design flexibility can also arise whenever the organisations commissioned by the project sponsor to deliver and eventually build a project outcome have limited responsibility in regards to its future operational costs and the extent the asset will cope with changes in the environment. For instance, some organisations may avoid including in their bids the costs of design flexibility to remain competitive (Laryea & Hughes, 2011; Taylor, Garvin, & Ford, 2012). The question of *who pays, when, why, and how much* is therefore central to capital project front-end strategizing. These projects invariably require different parties to coalesce their visions under uncertainty, urgency, and resource constraints into a concept that they can afford collectively and simultaneously ensures the operational longevity of the asset.

## Conceptual Context and Research Gap

Extant research in the management of capital projects and design has inadequately addressed the tensions arising from the need to trade off capital investments in design flexibility with other investments more likely to pay off in the short-term. The decision to invest in flexibility to mitigate the risk of costly changes invariably unfolds when capital resources are scarce at *front-end strategizing* – the period upfront in the project development lifecycle when key stakeholders need to assess alternative design concepts and negotiate a concept to progress into the next project stage (Miller & Lessard, 2007; Morris, 1994). Project teams have been exhorted to implement risk management practices to shield project delivery from the eventual occurrence of foreseeable change in requirements and standards, technological developments, and stakeholders’ opposition to the project (PMI, 2004). These recommendations emphasise the value of change controls and governance structures to ensure the business case underpinning each change request is assessed before a change can be instructed to project teams. This way changes that add value can be endorsed to ensure the effectiveness of the project outcome. Changes that fail to deliver value can be rejected. These recommendations, however, fail to acknowledge that the design definition itself will affect the potential impact of late changes to project delivery. Rather, the recommendations tend to fall under instructionist approaches that emphasize the pre-specification of stages to identify, estimate and respond to risk (Pich, Loch, & Meyer, 2002). Kahkonen (2006) argues that there is a fundamental need to improve risk management practices, especially regarding risk concepts and risk perceptions as well as in terms of providing a more holistic approach that attends to the needs of the different stakeholders. As Lenfle and Loch (2010) put it for the case of product development projects, practices that overemphasise the application of risk management to protect efficiency are bound to overlook opportunities to create value through investments in flexibility and novelty that will make the project outcome more effective. The difficulties in reconciling calls for investing in flexible solutions at risk the investments will not pay off with pressure to reduce capital costs under conditions of uncertainty have motivated calls for building options logic into project front-end strategizing (Gil, 2007; Miller & Lessard, 2007).

Options logic posits that strategy can be used to gain advantage under conditions of uncertainty (Black & Scholes, 1973; Merton, 1973). The aim of option-pricing theory is to provide analytical methods to guide the investor into making strategic investments under uncertainty that will enable investors benefiting from upside scenarios while limiting losses on the downside, i.e., options logic introduces an asymmetry in the probability of distributions of payoffs (Merton, 1998). Real options theory draws from analytical studies on financial options, and explores their applicability, not to pure financial investment decisions but to decisions to invest in physical assets (Amram & Kulatilaka, 1999; Smit & Trigeorgis, 2004; Trigeorgis, 1996). Studies in real options have predominantly applied analytical methods to price capital project investments with built-in options (e.g., Lee, 2007; Smit & Trigeorgis, 2004; Zhao et al., 2004).

Despite the advances of real options science since the mid-1980s, when options pricing models began to be used to value investments in real assets, and despite the current availability of various analytical methods to help assess capital investments, the uptake of the real options approach in capital investment practice has been slow. In 2002, for example, Ryan and Ryan (2002) indicated that 88.6% of Fortune 1,000 companies had rarely or never used real options. Five years later the figures in regards to adoption had hardly changed, when Block (2007) reported that only 14.3% of Fortune 1,000 companies were using real options. The slow rate of adoption of real options theory in practice is in marked contrast with Copeland and Antikarov (2001)’s predictions, which suggested that the real options valuations would take off and dominate strategic investment decisions within a few years. Admittedly, examples of successful adoption of real options have been found. However, they tend to be observed in industries where large investments with uncertain returns need to be made (Triantis & Borison, 2000). Anecdotal evidence also suggests that real options methods have been mainly applied to sophisticated analysis of capital investment decisions to acquire technology, energy systems, and utility companies (Block, 2007).

In contrast, evidence is limited on applications of real options pricing to inform more mundane design decisions in capital project front-end strategizing (Kalligeros, 2006). In these setings, the payoff of having an option can be limited relative to major strategic investments, which restricts the amount of time and effort that project teams can afford to dedicate to assess the option. Also, the cost of buying the option itself might require an upfront investment that is not negligible relatively to both the potential payoff it can provide (if uncertainties resolve favourably) or to the downside risks it mitigates. Therefore, the use of sophisticated analytical real options tools for mundane design decisions might offer a poor fit. An application of real options pricing methods can also be challenging if not overwhelming at front-end strategizing due to a conflation of reasons notably difficulties in making reliable assumptions, in ensuring that the analytical models stay tractable, and in developing simple but accurate analytical representations of real-world problems (Bowman & Moskowitz, 2001; Kalligeros, 2006; Lander & Pinches, 1998).

Due to the reluctance among practitioners in using real options pricing models, an alternative research stream has gained traction in the areas of assessing technology and R&D investments: real options reasoning (MacMillan, Putten, McGrath, & Thompson, 2006; McGrath & MacMillan, 2000; McGrath, 1997). Real options reasoning proposes to use options logic in order to develop qualitative methods that can support decision-making under uncertainty. The aim is to preserve the logic of the real options theory to assess the value of flexible solutions whilst sidestepping the difficulties of quantitative modelling. McGrath and MacMillan (2000), for instance, develop a method that translates the parameters derived from options pricing into a series of qualitative statements, and asks managers to specify their level of agreement with each statement before prioritizing technological options and allocating resources. Other authors (MacMillan et al., 2006) have further real options reasoning applications into methods that aim to support longitudinal decision-making processes under uncertainty, providing mechanisms through which decision-makers can ensure the periodic validation of assumptions and update of rationales. Similarly, Angelou and Economides (2008) have developed a decision-making support framework that combines real options analysis and analytical hierarchy process to help teams prioritize investment in a portfolio of information and communication technology projects.

Some anecdotal evidence points to rudimentary applications of real options reasoning in capital infrastructure projects. In the UK, for example, a health trust has spelled out in the tender documents that the consortiums bidding for developing and operating new hospitals through a private finance initiative (PFI) should ‘future-proof’[[1]](#footnote-1) the design, factoring in the costs for building pre-specified flexibilities upfront and for exercising them in the future if need be (Lee, 2007). Likewise, informal and largely intuitive options logic has informed the write-up of the design brief that safeguarded the economical adaptation of the largely integral design of Heathrow airport’s Terminal 5 to future changes in operational requirements (Gil, 2007). Extraordinarily, however, empirical studies suggest that capital projects teams rarely – if at all – receive training on options logic (Ford, Lander, & Voyer, 2002; Gil, 2007; Kalligeros, 2006). Admittedly, the cost of developing a sophisticated real options pricing model to assess relatively mundane design decisions at front-end strategizing may be disproportionate to the potential benefits that the model could generate. But an excessive reliance on informality and intuition to inform decision making in design flexibility makes decision outcomes a lot more vulnerable to short-term thinking, reduces accountability, and makes the whole collective decision-making process also more vulnerable to the self interest of the more vocal or politically strong parties.

The existing gap in the provision of suitable methods to support mundane design decision-making at the project front-end strategizing creates a research opportunity. On the one hand, sophisticated real options analytical models fit poorly with the nature of mundane early design decisions. On the other hand, intuitive assessments of future-proof decisions do not offer an alternative because they are vulnerable to misjudgement and lack of accountability. This gap provides the motivation for this doctoral research. The ultimate purpose is to develop a formal framework to support design decision-making at project front-end strategizing drawing from real options reasoning. The underlying hypothesis is that adding an options-like formalisation to early design decision-making can improve the quality of the front-end strategizing process and of its outputs in capital projects. This framing is called *capital design for evolvability.* The aim of design for evolvability is to create affordable design assets that can adapt economically to change over their life-time. The idea of designing a system to evolve is not entirely new. Drawing from evolutionary studies in biological systems that seek to observe and explain how organisms naturally changed across generations, Gagliardi et al. (1996) discuss the mechanisms that dictate how man-made systems can technologically evolve over time. They develop and test prototypes of evolvable systems in the area of real-time computing before broad-scale or commercial development of these computer artefacts. More recently, Beesemyer et al. (2011) contrast biological and technological studies to yield insights on prescriptive design principles for designing for evolvability. Both studies theoretically postulate principles or mechanisms that man-made commercial product designs such as the design of a car platform need to attend to in order to evolve over time as technology and user needs change. In commercial product development, the purpose of design for evolvability is therefore to ensure that the design can be reused from one project-based new product development process into the next. The design principles include: system modularization to allow easy replacement of small parts without comprising the whole system, selection of crucial modules that should be immune to changes to reduce costs of adaptation of the system, and definition of common interfaces to allow compatibility among different modules (Beesemyer et al., 2011; Gagliardi et al., 1996).

The purpose of capital design for evolvability is however different. In this world, project sponsors typically have fewer opportunities to exploit an existing design over time, which limits design longevity. Of course there are exceptions. Engineering consultants often design base cases of by-pass viaducts that can be reused from one highway project into the next. Another exception is the case of Intel’s Copy Exactly policy, which instructs the capital project teams to reuse proven designs of new high-tech semiconductor fabrication facilities (fabs) from one project into the next. This approach aims to compress the time to develop and ramp new fabs (Terwiesch & Xu, 2004). It can work fine if the manufacturing tools the new fab will host have not suffer major changes relative to the tools in the old fab. But empirical studies have suggested that the reuse of fab designs can backfire if the tool technology has evolved in fundamental ways; or if there are major differences in local requirements from one project to the next (Gil & Beckman, 2007). Another obstacle to reusing capital designs is the intermittent nature with which sponsors of capital projects initiate new projects. For example, the time lag between the conclusion of Heathrow’s airport Terminal 4 and the start of Terminal 4 was around 20 years (Gil & Tether, 2011). A similar intermittency has been observed in new hospital development in the UK. Although new hospitals are constantly being developed, new hospital projects are an intermittent activity for the health care trusts setting the local requirements (Barlow & Köberle-Gaiser, 2008).

Hence, capital design for evolvability aims to develop designs that enable the actual asset to cope economically with the occurrence of foreseeable changes in requirements during project delivery and later over the asset’s operating life-time. The conceptualization and validation of novel framing to design for evolvability at capital project front-end strategizing is the core purpose of this research. The approach is not new in the world of technology and R&D investment (MacMillan et al., 2006; McGrath & MacMillan, 2000). To the best of our knowledge, however, extant research has not yet combined literature in the management of capital projects and real options reasoning to develop and experimentally validate a formal design for evolvability framing. Cardin et al. (2012) recent experimental study is closer to this research, but has focused on evaluating the effects of educational training to raise awareness about the importance of factoring in the value of design flexibility under uncertainty when undertaking net present value analysis of a capital investment. Unlike our study, however, Cardin et al. (2012) experimental study is grounded on a simple front-end strategizing process that involves but one key decision-maker.

In contrast, our empirical study of front-end strategizing practices at Network Rail reveals front-end strategizing is often intertwined with challenging multilateral negotiations between equally legitimate and powerful stakeholders. And each stakeholder brings different and often conflicting needs to the project front-end. This research therefore aims to explore the value added of design for evolvability under conditions of uncertainty and plurality of stakeholders. Importantly, this study also develops theory on capital design for evolvability that factors in the affordability constraints inherent to front-end strategizing capital projects. Albeit seldom acknowledged in real options literature, the question of who pays the costs of the options must inform any effort to capital design for evolvability that unfolds in a multi-stakeholder environment.

## Research Purpose, Objectives and Research Questions

The purpose of this research is to build theory and methods on capital design for evolvability. Specifically, the research aims to address the question:

How can capital assets be best designed to ensure that they can adapt and evolve economically to cope with foreseeable changes in design requirements over project delivery and operational life?

To achieve this purpose, this research will first empirically investigate the nature of early design decision-making in capital projects involving various relevant stakeholders, and particularly the extent to which project teams adopt options logic to support decision-making. The motivation for this empirical work is driven by three questions:

R1: To what extent capital project teams may intuitively use options thinking to support early design decisions under conditions of uncertainty?

R2: To what extent is it feasible to assume that capital project teams may be willing to adopt real options analytical models at front-end strategizing capital projects?

R3: What challenges do capital project teams face when making early design decisions under conditions of uncertainty?

Based on the cross-fertilization of the empirical findings with extant research on options logic and the management of capital projects, this doctoral research will develop and validate an original proof-of-principle of a formal method to support capital design for evolvability. The development of the proof-of-principle aims to: (a) verify the theoretical feasibility of using a formal method to help decision-makers incorporate options logic – both in terms of lexicon and structured procedures – to support early design decision-making at front-end strategizing capital projects; and (b) investigate as to whether a formal design for evolvability framing can improve the quality of the front-end strategizing process and its outcomes, particularly when multiple stakeholders have to coalesce their conflicting interests into a unified vision for the design concept under conditions of uncertainty. Through a two-group controlled experiment that simulates the front-end strategizing process of a real-world capital project, this doctoral research seeks to validate the core proposition that a formal design for evolvability framing adds value at front-end strategizing along three core dimensions: effectiveness, efficiency, and satisfaction.

## Manuscript Structure

This manuscript consists of eight chapters structured as follows. Chapter 1 introduces the problem of trying to conceptualise large-scale infrastructure assets that can accommodate foreseeable changes in requirements at reasonable economic costs in the future. This section discusses the motivation for this research and articulates an opportunity to advance existing research. The section concludes by presenting the purpose and objectives of this research, and the research questions embedded in the study. The subsequent chapter presents an in-depth review on the relevant literatures on the management of risk in capital projects and real options. The review discusses the motivation for combining two research streams that have remained largely disparate. Chapter 3 describes the research methodology. It explains why this research combines field-based research (exploratory and in-depth case studies) with lab-based experimental research. The subsequent chapters present the empirical findings of an exploratory case study on the development of the Upton-upon-Severn Viaduct, a £3.5M project sponsored by a local authority to replace a structurally deficient viaduct (Chapter 4) and of front-end strategizing practices at Network Rail, the owner of UK’s rail infrastructure (Chapter 5). These two chapters discuss how the real options analytical tools can be too complex for supporting early mundane design decisions at the project front-end. The findings also reveal that despite the use of options logic in practice, this is largely intuitive. Chapter 6 then describes the development of a novel options-based framing to support front-end strategizing of new infrastructure development (capital) projects. The subsequent chapter discusses the validation of this framing using a two-group controlled experiment grounded on a real-world capital project. Finally, Chapter 8 discusses the conclusions and contributions to theory and practice of this research. It also discusses the limitation of the research and points out future research opportunities.

1. Future-proof is a practitioners’ jargon referring to designs with provisions built-in to mitigate the risk of costly adaptation to foreseeable changes in design requirements in the future. [↑](#footnote-ref-1)