Futureproofing Complex Infrastructure Projects Using Real Options

Keywords: Uncertainty, Complex projects, Flexibility, Infrastructure

Abstract

Existing project performance measures in the infrastructure sector focus on construction performance (time, cost, quality) and pay less attention to lifecycle performance. The consequence of this shortsighted perspective is that decisions taken early lead to poorer solutions. Infrastructure that should last centuries quickly becomes inadequate, leading to costly reconfigurations. Real options reasoning can help managers to overcome this issue by unlocking lifecycle performance thinking in complex infrastructure projects. Real options reasoning enables managers to explore the value of flexibility by employing futureproofing strategies during the development process. From analysis of interviews with experts in healthcare infrastructure, we observed that projects that led to obsolescence were developed using tight design briefs and were focused on capital targets, and decision-makers were less invested in the concept of futureproofing. On the other hand, projects that were futureproofed followed a loosely-defined design brief and shifted focus towards whole-life targets. We make five recommendations for futureproofed infrastructure.

1 Introduction

Infrastructure is a critical foundation for much of our economic and social life. Infrastructure needs continuous reconfiguration to accommodate new technologies, changing customer needs, climate change, and unexpected events. There is a $5.5 trillion spending gap between now and 2035 to deliver infrastructure that is futureproofed and climate-resilient [1]. Hence, we need to develop strategies for futureproofing infrastructure from the front end, when the infrastructure is planned. In this context futureproofing is “a proactive planning and management initiative and process employed by owners and the supply chain for mitigating risks found in asset management that acts as an urgent need against uncertainty” [2, p.12]. The big question is: “How can practitioners, particularly decision-makers, futureproof infrastructure?”

In this paper we discuss Real Options Reasoning (ROR) as an ideal framework for futureproofing complex infrastructure [3]. During the development process decision-makers can engage in informal futureproofing talks using real options to plan projects able to cope with future uncertainty [4]. Real options can include the decision to expand, defer or wait, or abandon a project entirely. For instance, in dealing with the construction of an infrastructure (such as a hospital), a decision-maker could decide to buy a plot of a land bigger than what is needed at the moment, but which would provide valuable space for expansion, if needed, in the next few decades. Another example might be to include an additional system and/or pipeline that would allow the hospital to be connected to a district heating system if the local city goes on to develop one. These “options” come at a higher upfront cost but provide flexibility that can reduce cost later in the infrastructure lifecycle. These options can futureproof an infrastructure. Real options reasoning deals with the dilemma of flexibility versus commitment [4], [5], highlighting the benefit of managerial flexibility under uncertainty [5], [6], and how flexibility influences value creation. ROR is useful when decision-makers cannot precisely quantify the value of operating different options, either because the information in unreliable or not obtainable, or the firm does not have the required resources and capabilities.

Some decision-makers engage in ad-hoc futureproofing talks during the process of infrastructure development. However, this useful process is not clearly presented in the literature or widely adopted by practitioners. We analyzed interviews with senior managers from health estate infrastructure projects, alongside project documentation, to address the question: *“How do futureproofing decisions develop in talks between clients and supply chain actors in complex infrastructure projects?”.*

2 Why is futureproofing important

Infrastructure represents enormous investment and commitment of resources for a country’s economy and its communities. Governments and infrastructure owners around the globe have a history of underinvestment in infrastructure adaptations needed to mitigate both predictable (e.g. the effects of climate change) and unpredictable events (e.g. a pandemic). However, industry leaders have recently started to explore how they can futureproof infrastructure, protect cities from stress, and prepare organizations for sweeping change [1].

The benefits of futureproofing are clear: decisions at the project front-end can greatly benefit stakeholders and decrease the cost of the infrastructure across its lifecycle. In essence, by carefully planning and designing infrastructure assets that could easily accommodate operational change (as in the examples above), their functional life can be extended. As a result of futureproofing, the organization owning the infrastructure assets will be able to realize more value, compared to taking a traditional project management approach focused on design and construction.

A futureproofing strategy can be incorporated into a project's lifecycle [7]. For instance, when developing a business case, investigation of future services based on likely technological advances of service equipment can be considered. Healthcare estate development is a good example: home-based treatment, remote care and themed treatment are some of the future scenarios that can be considered when developing a business case. In addition, fast-track construction methods should be considered during procurement as features such as big floor plats, and regularly spaced ducting can address future uncertainty.

Ultimately, by carefully incorporating futureproofing from the initial stages of the infrastructure project, good organizational and asset performance can be achieved [7]. In contrast, as the infrastructure project advances towards its completion, the potential for cost savings reduces and the cost of applying changes increases.

During infrastructure development, decision-makers may talk about futureproofing, but, unless the talks are facilitated by formal plans and rules, they struggle to achieve consensus around topics such as who should pay for design flexibility [4]. The discussions can be driven by the preferences of those with most bargaining power.

To understand better how futureproofing talks with ROR are used by decision-makers, we investigated external and internal factors that may influence decision-makers in choosing the right strategy. External factors include legal and regulatory frameworks or organizational capacity of decision-makers involved in project delivery. Factors internal to the decision-makers include cognitive limitations and behavioral biases such as optimism bias.

3 Methodology and Setting

To investigate our research question, we conducted 32 interviews with senior managers from both client procurement and the supply chain. The interviewees were engaged in developing a variety of NHS (National Health Service) health estate projects. In 2013, the UK Department of Health issued a policy note calling for sustainable and futureproof health and social care buildings: “Buildings should respond to future changes in requirements, change of use, strategic perspectives, clinical medical drivers, national policy and changing climate” [8]. While the service continues to transform rapidly due to an aging population and rapid advances in technology, the estate has failed to keep pace with this service transformation. 43% of NHS estate is more than 30 years old, with many buildings not fit for purpose (i.e., not futureproofed) or needing significant upgrades to bring them up to a modern standard [9]. From previous studies we know that decision-makers may engage in ad-hoc futureproofing talks as part of infrastructure development. In our research we asked how ROR shaped discussions between a client and a consultant or contractor, the two most important decision-making roles in a health estate project. Secondary data (e.g. the NHS England business case approval process, Government’s Green book, and third-party reports on NHS property and estates) were also examined. The analysis led us to distinguish between cases that were successfully futureproofed and cases that were not. By comparing these cases, we were able to identify how futureproofing decisions using ROR can develop in discussions among the key stakeholders involved in the front-end of infrastructure projects.

4 Findings

In this section we present the findings in non-futureproofed cases and in cases that led to futureproofing.

4.1 Non-futureproofed cases

In cases in which futureproofing was not realized, we observed the following external and internal factors.

4.1.1 External factors

Capital targets: This factor originated in the relationship between the Government's policy directives and the service's performance. The service's delivery performance aimed to meet government targets, hence reducing capital cost (to meet set targets) was more important than achieving whole-life targets. Consequently, improving the estate by futureproofing received lower priority than service delivery performance after handover. A client-side Framework Director said: "for the Department of Health … [the capital cost saving target] is 14.1% … there is nothing within that strategy which talks about the whole-life cost [of the estate]".

Tight project brief: This factor related to the competing benefits of a tight versus loosely-defined project brief from the outset of the business case. According to the interviewees, in projects where futureproofing talks failed, solutions that were proposed by the supply chain were rejected, because they were perceived as being outside of the tight project scope. Despite new information becoming available as the project matured, the fact that the project brief was 'locked in' prohibited the additional information being used in the proposed solution.

4.1.2 Internal factors

Bounded thinking on future requirements: This internal factor draws on the idea of bounded rationality. Bounded rationality acknowledges the limitation in people's abilities to foresee consequences and to deal with complexity and uncertainty, in this case to identify future options. To cope, decision-makers simplify the problem using a set of heuristic rules to arrive at a solution that, in their eyes, is 'satisficing' or 'good enough'. For example, one interviewee explained: "Everything needs to account together… so that we can use [the building] at any given point in time in the future. And it is that bit that people do not get and they do not think about… we just do not think about [futureproofing] enough as a process." Interestingly decision-makers acknowledged their limited cognition - what a Sector Director referred to as "insufficient thinking".

Motivational gaps: This internal factor stems from the lack of personal commitment in employing ROR during the development process. This speaks to psychological theory which understands motivation as the driving force behind human behavior, without which intentional actions do not occur. The interviewees highlighted the difficulty of implementing futureproofing plans due to the different project values espoused by different agents in construction projects. In some cases, the decision-makers saw futureproofing as a tick-box exercise, indicating a motivational gap whereby they proposed futureproofing solutions that they had no intention of implementing. The motivational gap led to frustration and, ultimately, a suboptimal solution. Emotions can also guide and stop information search during discussions which include ROR.

4.2 Futureproofed cases

In successful cases, we observed the following external and internal factors.

4.2.1 External factors

Whole-life targets: Projects that successfully implemented ROR prioritized whole-life targets to identify where investments now would achieve savings later. Shifting the focus from capital cost of the project to whole lifecycle cost of the estate facilitated futureproofing. A Managing Director for a consulting firm explains this rationale: “Now if they [main contractor] know that every 15 years within that 35-year period they are going to do two complete refreshments before the handover of the building, they will therefore look at the flexibility because… they are looking for the cheapest price over the whole-life of the building!”.

Loosely-defined project brief: Projects that successfully implemented ROR adopted a more loosely-defined project brief. The project brief did not freeze prior to entering the detailed design phase, allowing negotiations to take place to reach agreement without compromising the solution. Similar conditions that enabled this ‘design fluidity’ have been noted in research on aviation infrastructure (e.g. London Heathrow’s Terminal 5 “last responsible moment”). This approach ensured progressive assurance is reached by enabling new information to feed into the project’s scope as the project progresses.

4.2.2 Internal factors

Iterative loop between problem and solution: Complex infrastructure projects are initiated by a set of requirements. This set of requirements prescribes *what* the final product (i.e. infrastructure) needs to accomplish for the society it serves. Here, what benefits the product will give to the users is identified. We call this the *problem space*. No product or design exists in the problem space, only a shopping list of needs. Experts then will design *how* the product will deliver the benefits. We call this *the solution space*. In the solution space, experts will outline the design of the product and the specific technology used to implement the product [10]. Not freezing the project brief before the design solution reaches the required maturity enables an iterative loop between problem and solution. These iterations resulted in both problem and solution being continually informed as the project matured, allowing solutions to develop and to be checked against the latest set of requirements. Clients and supply chain experts talked through possible options that were facilitated by the interplay of sacrificial systems, over-engineered systems and repeatable standardized systems. Table 1 summarizes how the iterative loop between problem and solution resulted in several futureproofing strategies being assembled.

Table 1. Examples of futureproofing design strategies

Design Strategy	Description
Sacrificial systems	Designing systems that do not incorporate any additional sub-systems so can easily be demolished in the future without implications to adjacent systems.
Over-engineered systems	Designing systems such as foundations for services and functions that may be unused in the present but that could be useful in the future.
Repeatable standardized systems	By employing standardization techniques and ensuring repeatable spaces, the supply chain achieves economies of scale in design effort, materials procurement, and constructability.

Making the case for affordability: In a ROR approach, the outcome of this internal factor was the ultimate decision on whether a specific combination of plausible interconnected design options was affordable. The participants' propositions to the client for affordable solutions were also informed by previous cases. The design incorporating ROR needed to be perceived as affordable to be attractive. To be perceived as such, a futureproof solution should also feature payment-by-results, whereby additional investment necessitated by ROR is justified in the business case with reference to independent verification of results (e.g. more patients can be admitted). Decision-makers compared past projects' affordability to inform their ROR and to verify the viability of the proposed solution.

5 Discussion

Managers often rely on their intuitions and experience to think about the issues they face, the options available, and the value of each option. They recognize patterns in the data, usually in the form of events, taking actions that worked in past projects. Managers should be encouraged to reflect on why some options lead to certain outcomes, and to discover what causes them by tracking the external and internal factors. In this setting ROR is an ideal tool to foster critical thinking leading to futureproof infrastructure.

Front-end decisions on design flexibility (or lack of) are hard to reverse because of their immediate project implementation. Thus, managers should employ ROR from the outset of the project to become more aware of the impact of their decisions. We propose five recommendations to promote ROR in the development process of complex infrastructure projects.

1. Decision-makers need to promote budget flexibility and late lock-in. In an example, our participants shared how they managed to extend the initial budget regarding

the functional layout of patient rooms. Their approach challenged current thinking which was around 'cheap to build' and argued that if the project ended up being more expensive to run or would not provide flexibility in the future then they have not achieved their client's goal.

2. Decision-makers need to foster planning and design processes that allow for a loosely-defined project brief which is gradually informed as the project matures, instead of early fixing of design requirements.
3. Decision-makers need to shift assurance procedures towards whole-life targets instead of capital targets [11]. Thus, construction capital investments could bring futureproofing higher up in the agenda, and require that projects be benchmarked beyond time, cost and quality.
4. Decision-makers need to be aware of the limitations that cognitive boundaries and absence of personal commitment to futureproofing principles can bring. This recognition can enhance our understanding of how procurers and the supply chain can employ ROR to develop futureproof solutions and avert uncertainty.
5. Decision-makers need to create a costs database arising from unplanned changes during an asset's operational life. Such database could help decision-makers develop projects based on a lifecycle approach in order to reduce lifecycle costs [11], [12]. Beside the cost implications, the database should report the causes of change. Slaughter's [13] types of changes according to function (upgrade existing or incorporate new functions), capacity (structural changes) and flow (movement of people and materials) is a useful start. This will help decision-makers to understand how and why these assets evolved, under what conditions and timespan. They could draw conclusions on which real options [14] could, retrospectively, have averted or minimized the impact of these changes.

6 Conclusion

ROR enables decision-makers to deal with critical dilemmas such as the trade-offs between flexibility and commitment. In project studies, there is a consistent and established body of knowledge (e.g. PMBOK) emphasizing the importance of having all relevant details and information, so all key decisions can be taken right at the front end of the project (commitment).

Our approach here challenges this thinking, and advocates that because customers' needs evolve over time, their needs are best served by process flexibility to postpone design decisions and request late changes. However, keeping the options open during physical execution is challenging. Gains in the effectiveness of how infrastructure performs may come at the cost of lost efficiency in project delivery, increasing the time and/or cost required for project completion. Thus, decision-makers need a step change in their thinking of evaluating short-term concerns for efficiency over long-term effectiveness.

ROR supports such step change. ROR can help decision-makers in planning and delivering infrastructure which is resilient across its lifecycle. Our study establishes the significance of the individual decision-making process and identifies the external and internal factors that guide such thinking. Ultimately, we advocate that decision-makers should employ ROR in the early stages of infrastructure development.

Managers should not see these external and internal factors as a pick and choose menu that guarantees futureproofing. It is the constellation of all these internal and external factors that brings futureproofing outcomes to complex infrastructure projects. The recommendations from this article will help managers and executives seeking to navigate the difficult and challenging process of futureproofing complex infrastructure projects.

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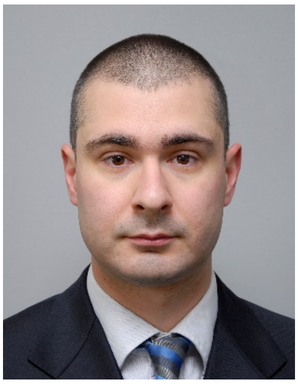

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