Talking about Futureproofing:

Real Options Reasoning in Complex Infrastructure Projects

Abstract

Complex infrastructure projects often attract criticism regarding their short- and long-term performance. An effective development process requires thinking about both present and future requirements. We employed the lens of real options reasoning to investigate the power of verbal theorizing, without the aid of analytical modeling, to add flexibility in the development process. Drawing on 32 semi-structured interviews with decision-makers involved in health estate projects, we examined if and how informal talks in the development process can lead to futureproof outcomes. Our findings synthesize and conceptualize relevant insights on iterative design thinking, affordability, bounded rationality, and motivational gaps as causal mechanisms for futureproofing talks and thus real options reasoning. The paper contributes to the planning and project studies literature dealing with futureproofing complex infrastructure projects.

Managerial relevance

Existing project performance measures, proposed by dominant theories in project studies, focus on capital project performance and pay less attention to lifecycle performance, leading managers to sub-optimal solutions. Real options reasoning could unlock lifecycle performance thinking in complex infrastructure projects by enabling managers to explore the value of flexible designs and by employing futureproofing strategies in the development process. We observed that projects that led to obsolete assets were developed using tight design briefs and were focused on capital targets, whilst motivational gaps influenced decision-makers' actions' and their thinking was bounded in

respect of future project requirements. We found that projects that were futureproofed followed a loosely-defined design brief and shifted focus towards whole-life targets. We make five recommendations for a futureproofed project: 1) consider budget flexibility in the way funds are released; 2) foster design and construction processes that allow for a loosely-defined project brief which is gradually informed as the project matures; 3) shift assurance procedures towards whole-life targets; 4) be aware that cognitive boundaries and personal commitment affect how decision-makers employ options thinking regarding futureproof solutions; and 5) maintain a cost database of the unplanned changes during an asset's operational life.

Index Terms— decision making, project management, real options reasoning, uncertainty.

1 INTRODUCTION

"We live in a time of extraordinary change", President Obama observed in his 2016 State of the Union address. Infrastructure, such as hospitals, universities, and power plants, need continuous reconfiguration to accommodate new technologies, customer needs, and unexpected events. It is necessary to develop infrastructure which is flexible enough to accommodate major changes across its lifecycle. Therefore, from the project phase, when the infrastructure is planned, designed and built, we need to develop strategies for futureproofing infrastructure. Futureproofing can be defined as "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" [1, p.12]. Complex infrastructure projects need futureproofing to deal with unexpected events and to be flexible in accommodating changing needs, uses or capacities [2], [3].

This paper presents Real Options Reasoning (ROR) as an ideal framework for futureproofing complex infrastructure. Decision-makers engage in informal futureproofing talks during the development process using real options to plan projects able to cope with future uncertainty [4]. Real options theory deals with the dilemma of flexibility versus commitment [4], [5], offering a framework for decision-making under uncertainty [5], [6].

Real Options Reasoning (ROR), which is a common approach to real options decision-making [7], is a strategic and intuitive way of thinking that encompasses the formulation and testing of hypotheses based on verbal theorizing without using analytical modelling [5]. ROR enables decision-makers to develop infrastructure able to accommodate changing requirements throughout its operational life [8], [9]. ROR highlights the benefit of managerial flexibility under uncertainty [5], [7] and how flexibility influences value creation [10], [11]. ROR is useful when decision-makers cannot 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 [12].

Regarding complex infrastructure projects (e.g. hospitals), existing performance measures focus on capital project performance (e.g. delivery on time and budget) and pay less attention to the lifecycle performance of the infrastructure [3], [13]. ROR promotes lifecycle performance thinking, yet there is limited evidence of how and under what conditions this occurs. Building from these insights, in this paper we deal with the following research question: "How do futureproofing decisions develop in informal futureproofing talks among clients and supply chain actors in complex infrastructure projects?".

This empirical study's focus is on the informal talks between decision-makers. We considered how ROR-influenced discussions during the development process can lead to more sustainable, futureproof infrastructures. Adapting the ideas of ROR, we developed a processual model showing how futureproofing decisions develop over time via informal talks among clients and the supply chain, using health estate projects as the context.

2 RESEARCH BACKGROUND

2.1 Real Options Reasoning in Complex Projects

The operational phase of an infrastructure asset involves substantial uncertainties [14], [15]. When decision-makers recognize the need for futureproofing, ROR can offer a strategic framework, in which flexibility facilitates dealing with uncertainty [16], [17]. Strategic options, evaluated with ROR, provide decision-makers with the opportunity to hedge their bets in the face of uncertainty; by having the ability to make midcourse corrections, they can better manage uncertainty [18] by improving the asset's upside potential while limiting downside losses [6].

Trigeorgis and Reuer [5] urged the expansion of ROR to consider management and organizational realities including bounded rationality, organizational structures, and control mechanisms, . Bounded rationality is often cited in project studies as a causal mechanism of poor infrastructure project performance [19]. Causal mechanisms are a central element of our study and refer to "a constellation of entities and activities that are organized such that they regularly bring about a particular type of outcome, and we explain an observed outcome by referring to the mechanism by which such outcomes are regularly brought about." [20, p.325].

Recently there has been an energetic debate in the literature about infrastructure project performance and failings. Flyvbjerg and colleagues [21]–[24] have stressed that complex projects are very often over-budget, late and deliver far less benefit than originally expected. Key reasons for this behavior are proposed to be optimism bias and strategic misrepresentation. Love and colleagues [14], [25]–[28] argued that the performance of complex projects (in both short- and long-term) is not as negative as depicted by Flyvbjerg's group. Moreover complexity and uncertainty are key determinants for cost overrun [14], [26]. Complexity and uncertainty are not just technical, but can be due to long-term contractual arrangements [13], or how people interpret information [29].

According to Love and colleagues, during the development process, both capital and operational expenditure need to be considered and a balanced approach is needed taking both an outside and inside view [30]. The outside view recognizes that projects of a similar nature and scope should be used as a reference point when assessing a project [31]. The inside view asserts that project estimators only consider the information that is made available to them for that particular project. Love and colleagues propose that scope changes, errors and mistakes lead to non-futureproofed projects and recommended that decision-makers should consider delivery strategies; and asset management [13], [15], [32] as conditions that can form the basis of ROR in futureproofing talks.

2.2 The Context of Futureproofing Talks

ROR is most valuable when the key assumptions of real options value can be identified and synthesized conceptually, even if options cannot be quantitatively valued [7]. Decision-makers use ROR, but, unless the talks are facilitated by formal plans and rules, they can struggle to achieve consensus around topics such as who should pay for design flexibility [4], which can be driven by the preferences of those with most bargaining power. Thus, understanding in detail the *contextual conditions* is essential for appreciation of how ROR is applied by decision-makers, and deriving a more detailed and nuanced understanding of futureproofing in the development of infrastructure.

Earlier research examined how the internal processes of a project are influenced by its historical and organizational context highlighting that a contingency approach to project success is needed [33]. Building on this understanding, an investigation into how contextual conditions enabled project success in one setting but not on another yielded proposals for three contextual conditions: structural conditions e.g. legal and regulatory frameworks; institutional conditions e.g. organizational capacity of decision-makers involved in project delivery; and managerial conditions, e.g. project leadership [34]. Futureproofing talks are thus susceptible not only to pitfalls due to cognitive biases and organizational pressure [35], but also to contextual conditions.

2.3 Social Causal Mechanisms for Futureproofing

Our ROR processual model comprises of a set of context-mechanism-outcome (CMO) configurations [36] explaining how outcomes result from causally relevant processes. In process studies these are termed causal mechanisms [37]–[39]. In the absence of these mechanisms, the outcome will not materialize. A causal mechanism enacts its causal powers when it is combined with other mechanisms within a set of enabling conditions. The conditions form the context in which mechanisms may trigger observable actions or events [39]. Furthermore, a mechanism may be *active* or *passive* - its activation can lead to a desired outcome if that mechanism operates within an appropriate context. Causal mechanisms can be further analyzed into change mechanisms, and problem mechanisms [36]. Change mechanisms can cause events and problem mechanisms can block or neutralize those events.

As individual agency enables differing positions and responses within any context, the social domain is characterized by multiple causal mechanisms [40]. Social causal mechanisms are neither invariant nor universal - they influence but do not determine human behavior [38]. The basic entities of social causal mechanisms are individuals, their actions and relations [38]. Four assumptions can be made about social causal mechanisms [38]: (1) They are identified by the kind of effect or phenomenon they produce; (2) They are irreducibly causal; (3) They have structure; and (4) They form a hierarchy.

Social causal mechanisms are composites of the situational (macro-micro level); action formation (socio-technical action); and transformational (micro-macro level) mechanisms [41], [42]. Macro-micro level mechanisms explain which social structures enable and constrain individuals' actions and shape their desires and beliefs. For example, a project safeguard [8] which is defined as the design and physical development work for embedding an option in the project, can act as a situational mechanism which enables possibilities for flexibility for infrastructure owners. Action-formation mechanisms explain how a combination of individual desires, beliefs and action opportunities generate a specific action. Continuing our example, individuals are more likely to invest in project safeguards if they believe that the option will be exercised. Micro-macro mechanisms explain emergent behavior, that is, how individuals through their actions generate various intended and unintended outcomes at macro level. Knowing that the option stemming from safeguarding will be exercised in the foreseeable future, leads individuals to favor design and physical development works and use of modular components that result in futureproofed infrastructure. Previous work on futureproofing can be interpreted through the lens of causal mechanisms. *Common vision* is an important mechanism for futureproofing and determines the decisions leading to staging, deferring and even abandoning a project [43]. The relevant conditions in which this change mechanism has operated, and resulted in futureproofed projects, included the formation of effective project coalitions and strong involvement by the executive board decision-makers. In contrast, *lack of clear strategic vision* by the client, under conditions of weak cooperation ties between the two main parties involved, operated as a problem mechanism which discouraged decision-makers from introducing futureproofing into infrastructure projects [44]. While causal mechanisms such as *utility maximization* and *bounded rationality* operate as problem mechanisms and prevent futureproofing, contextual conditions such as intentional choice architecture can change outcomes [45] by prompting stakeholder groups' behavior towards more futureproof outcomes. Despite the causal mechanisms outlined above, there is limited knowledge of the social causal mechanisms for futureproofing in the development process for infrastructure. Furthermore, few studies have considered the contextual conditions surrounding ROR.

2.4 Healthcare as an Example of Complex Context

Like most complex infrastructure projects, health estate projects are characterized by great uncertainty due to numerous internal factors (e.g. advances in internal policies) and external factors (e.g. technological advances, demographic trends). In this study, the setting was the UK NHS (National Health Service). In 2013, the UK Department of Health (DH) issued a policy note [46] 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" [42:15]. 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 [47]. 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 [48]. This background informed our empirical study and research question as explained in the next section.

3 Research Methodology

3.1 Research Design

This empirical study was qualitative [49] and used an inductive approach. Process modelling [37] was applied to identify social causal mechanisms which generated observed events, as well as the conditions in which these mechanisms operated. The study employed a configurational perspective [36], [50] to explain outcomes by analyzing configurations of possible mechanisms and context-variations. Fig 1 summarizes the research design.

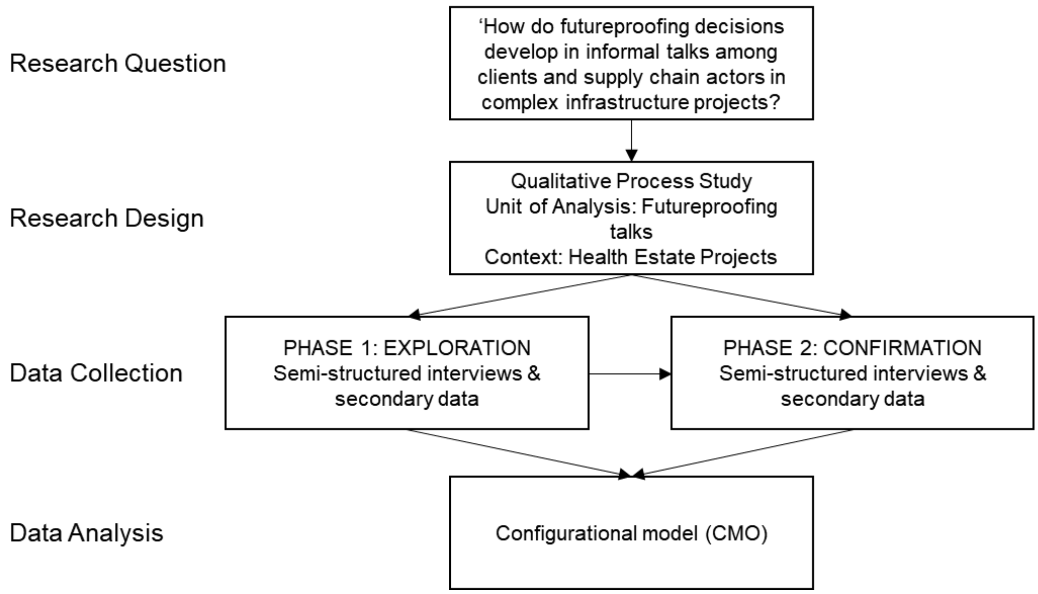

Fig 1. Research design

The unit of analysis was informal futureproofing talks. Previous research on infrastructure projects has shown that decision-makers engage in ad-hoc futureproofing talks, to address the trade-offs between rigid versus flexible designs, using ROR logic [4]. In terms of ROR, the analysis of such talks is important to explore normative statements such as managerial orders, operating procedures, legal requirements and understanding of how and why involved parties facilitate these discussions to achieve a desired (i.e. futureproof) outcome. We studied how ROR shaped discussions between a client (principal) and a consultant or contractor acting as their agent, the two most important decision-makers in a health estate project.

3.2 Data Collection

The study was designed following the two stages outlined in Sobh and Perry [51] and harnessed both primary and secondary data. The first stage was exploratory, with theory being gradually built as 26 interviews of 60 to 240 minutes were conducted, as detailed in Table I. Secondary data (e.g.

the NHS England business case approval process, Government's Green book, third-party reports on NHS property and estates, and participant-recommended sources) were also used (Table II).

The interviewees were senior managers engaged in developing a variety of NHS health estate projects. A purposeful sampling strategy [49] was employed. Initially, 18 participants, with experience in futureproofing during the development process, were identified through personal social networks. The interviewees recommended eight additional individuals.

Table I Interview protocol

Interview theme	Questions
Interviewee background	What is your role in the business? What is your project role? How many years of experience do you have in construction and how many in healthcare projects? What kind of projects where you involved in the last 10 years?
Perceptions about what futureproofing means, project challenges and organizational pressures	What does futureproofing healthcare facilities mean to you? What are the main barriers to future-proof healthcare facilities during the development process? How does futureproofing impact on the decision-making (prompt: during the development process; other project phases (e.g. design)? What are the current and future drivers for futureproofing? What factors for futureproofing are important in the development process?
How to respond to those pressures	How do you evaluate the cost of change in projects in the development process? How do you evaluate the duration of change in projects in the development process? Does the contract enable or hinders futureproofing? In what ways? Which strategies are most suitable to implement facility type changes? What is the role of standardization? What information would be useful in terms of making decisions about the future of the asset?

In the second stage, six interviews of between 40 and 80 minutes were conducted. The participants were selected for their expertise in developing best practice guidance on the design and planning of new healthcare buildings and on the adaptation or extension of existing facilities [46]. This stage focused on the examination of causal reasons for observed phenomena and sought to confirm or disconfirm our theoretical developments.

Table II summarizes the two stages of data collection.

Validity and reliability of the data were achieved through: selection of participants with relevant experience at senior management levels and in the focal context; consistent use of a pre-prepared interview protocol (summarized in Table I); provision of the interview protocol to participants in advance of Stage 1 interviews; use of the same interviewer for all interviews; audio-recording and verbatim transcription of the interviews; triangulation with secondary data from government, NHS and project sources; and finally presentation of the findings to a different set of experienced and senior professionals in Stage 2.

Table II Data collection stages for sources (adapted from [51])

Stage characteristics	Stage 1: 2013-2014	Stage 2: 2019
Objective	Explore dynamic decision-making in futureproofing healthcare projects	Focus on causal reasons for futureproofing and confirmation or disconfirmation of findings.
Primary sources	Interviews: total 26 Procurers: 16, Supply chain: 10	Interviews: total 6 Procurers: 6
Secondary sources	Estate strategies, guidance documents, templates and forms, policy documents, drawing samples, third party reports, news and blog articles.	Estate strategies, guidance documents, templates and forms, policy documents, drawing samples, third party reports, news and blog articles.

Note: The total number of interviews was 32. Archival records totaled 48.

3.3 Data Analysis

We used the CMO model [36] in the analysis of the data and present four causal mechanisms along with their context-variations. The configurational perspective assumes contingent causality [52] explaining in what contexts a mechanism or a combination of mechanisms have the powers to cause a futureproof solution. Wynn and Williams's [53] four-step analytical approach was employed to structure the data analysis (Table III) and NVivo software was used in analysis of the transcripts and secondary data.

- In step one, open coding was performed to unpack key events [37], i.e. the sequence of events describing how futureproofing talks unfolded over time. While some events were deemed important a priori (e.g. business case initiation), other events were identified during data analysis (e.g. preparing the supply chain response). This coding procedure allowed the establishment of a generic timeline of events to describe the general progression of procurement of healthcare projects.
- In step two, the context and its conditions were identified. In configurational analysis, there is no presumption about the level at which the contextual conditions are situated [54]. In the

context of our analysis, contextual conditions described the setup in which informal futureproofing talks took place that led to either futureproof or non-futureproof health estate projects.

- The third step was retroduction, i.e. we made use of the social causal mechanisms as the basis for our explanation. Through retroduction, the analysis tested the explanatory power of each candidate mechanism in relation to the empirical evidence [53]. This approach yielded four social causal mechanisms that could explain the sequence of events. Examples of data excerpts and their preliminary and final coding is presented in Table IV.
- In step four, the four mechanisms were further analyzed to establish the contextual conditions and outcomes, i.e. the result of the interaction of the components in a configuration setting. A successful outcome is defined here as a project which incorporates options thinking and is thus futureproof. The above steps enabled outcomes to be explained by analyzing configurations of possible mechanisms and context-variations.

Table III Data analysis steps (adapted from [53])

Step	Tasks
1. Explication of Events	Basic description of case, setting the scene Summary and streamlined version of events as they occurred. Use of direct quotes to show perception in the empirical domain Description of events includes details of key actions and outcomes Documentation of the effects (or not) of change
2. Explication of Structures and Context	Identification of social and physical structures (agents, rules), and relationships among them Identification of context and necessary conditions Description of contextual conditions Identification of changes (or not) to the structure Description of emergent properties
3. Explication of mechanisms	Identification of proposed mechanisms Use of abduction reasoning to logically support the mechanisms Identification of problem and change mechanisms Identification of alternative mechanisms that could exist Validation of proposed mechanisms over alternative mechanisms
4. Configuration of contexts, mechanisms and outcomes	Development of contextual typology Analysis of mechanisms to confirm contextual conditions and outcomes

Table IV Excerpts from data analysis

Quotations	Preliminary coding and identification of sub-category	Final coding
"Everything needs to account together, and it needs to be maintained and futureproofing itself so that we can use at any given point in time in the future. And it is that bid that people do not get and they do not think about. It is not just the client problem. We just do not think about it enough as a process." "I don't think it [referring to impact on their work] does a lot because at this point in time, I do not think we do it in detail. I think we do it in a very broad way, we say we will design this building so that the walls will be easily movable. We do not do it many other ways really." "Yes the client says they want futureproofing, but you have to be clear on what that might mean. It might mean something to do with the classification of cabling with the IT, it might be something to do with levels of security, it could be all manner of different things. If its futureproofing full stop, then you've got to say this is insufficient thinking."	Complexity of futureproofing as a process	Bounded thinking on future requirements
"Those stakeholders see very much on the here and now and what they need now and often these individuals will only be in a healthcare facility for perhaps another year and then they will move to another place." "We would love to be able to do that, but we have been told that we got to solve this problem now and that is what we focus on." "The fact is, do we really need to and the fact that we can do and whether the client wants it is two different things. It tends to be that you optimize the space you are given. It is not really used for saying OK what if we do this with the building in the future... 30 years is an awful long time and the stakeholders do not want necessary to get themselves involved."	Stakeholders shift future issues to future stakeholders	

4 RESULTS

4.1 Explication of Events

In the first step of analysis (see Table III), four main events were identified [37] in the participants' accounts of experiences on various health estate projects procured around the UK.

1) Initiating the business case: Business case development was triggered by the need for a new service and/or estate and complied with a series of guiding principles. The NHS required approval for funding to be released. All proposals needed to showcase specific criteria such as best value for money, affordability and deliverability, and demonstrable health economy support. The appraisal of business case options was required to demonstrate that various options had been considered, lessons learnt from past projects had been incorporated, and international comparative cases analyzed. This exercise considered high-level options however, the options are considered only as alternative solutions and are not interdependent. Often futureproofing was not explicitly considered and thus evidence of ROR was absent. For example, a procurer side participant shared:

“[futureproofing] is part of the brief, but I think there is … a lot of glimpse”. A health sector director said: “we would love to be able to do that [consider futureproofing], but we have been told that we’ve got to solve this problem now and that is what we focus on”.

2) Establishing the procurement route: Various procurement methods were mentioned in the context of futureproofing talks, which may be broadly classed into two categories: traditional engineering procurement and construction (EPC) contracts, and Private Public Partnership (PPP) contracts. Table V summarizes how the main decision-makers may have different values of what constitutes success. Where the NHS procures with its own capital, the supply chain interviewees felt that futureproofing talks were likely to be price dominated and the client would probably go for the cheapest solution, diminishing ROR. A Head of Division for a major contractor added: “The Trusts decide … but the design with the lowest price wins”. In the case of PPP projects, potential investors look for the most economical solution over the whole-life. The investors by employing ROR explored flexibility in terms of return on investment. A Managing Director for a major contractor explained: “The drivers for PFI [Private Finance Initiative] are totally different than NHS Capital Procurement, the PFI is driven by the banks and how much return on investment they can get. And if they are prepared to put some additional money up front to save a lot of money in the long term”.

Table V Definition of success for the main parties involved in a health estate project

	Traditional EPC contract	**PPP/PFI**
NHS	Usable, easily reconfigurable building in the long-term (>60 years)	Value for money for the duration of the contract, then a usable building that is easily reconfigurable.
Main Contractor	Profit at the end of contract. (construction handover).	Profit for the duration of the contract.
Subcontractors	Profit on the work done	Profit on the work done

3) Preparing the supply chain response: During informal talks about futureproofing, the interviewees identified three broad categories of weaknesses in implementing ROR whilst preparing the response. First, prejudices towards the concept of futureproofing: stakeholders saw futureproofing as a simple tick-box exercise. Second, reactions against existing processes: for example, a Design Director identified the constraints due to the project brief content as limiting the ability of the technical response to accommodate ROR prepositions. He said “The briefing is the main barrier; it constrains the approach. This is the primary concern… we would include flexibility in its full form [if not constrained by the brief]”. The last category is that of financial issues. Both procurers and supply chain participants highlighted that a financial weakness exists when incorporating ROR in the technical solution, specifically the justification for higher construction costs that will incorporate flexibility in the development. A Sector Director added: “You will win the work because you are the cheapest. So, you are not looking to duplicate anything when you are bidding”.

4) Initiating the project: The NHS process was to score all submissions and the proposal with the highest score would be awarded the project. Upon award, the client team and the winning team would meet to discuss the project requirements in more detail. At this point, the two teams would seek to deepen their communication to discuss ambiguities and the way forward. An iterative process of discussions would take place between project award and the initial stages of project initiation (cooling-off period). The two parties informally discussed further project details and clarifications before a formal agreement was made. The interviewees mentioned that at this point they would try to incorporate principles of ROR where possible. Some successful futureproofing design strategies that emerged from the interviewees’ accounts are listed in Table VI.

Table VI Summary of the database of futureproofing design strategies

Design Strategy	**Description and Verbatims**
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. “..because for example imaging equipment is getting smaller. So, would he want movable walls? [The client said] ‘We want highly acoustic efficient, thermally efficient, movable walls’. OK, well let us think about that. …I mean personally I think you can get to the point where some aspects of your design are as close to futureproofing as you could possible get them.” “Or it might be that the ultimate capability is completely sacrificial walls. This was a good example (points at the sheet). Sometimes flexibility is having a consulting room and at some point, flexibility is in either making one bigger one or making three smaller ones. So, you have this wall becoming completely sacrificial. And all your electrical services are running on another wall [points at the wall on the left side of the sheet].” “Finding ways so the medical staff will work more efficiently, e.g. by having movable walls, it will give them additional capacity if they require and that will increase productivity.”
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.

	"I suspect that the easiest way to futureproofing is to over-specify. If e.g. on the concrete slab, there is one case that it can be used as a ward, but it might become an X-ray room in 20 years' time, then the only way is to over-specify the strength of the concrete or beefing up the steel frames etc. I think the construction industry has to say the best way for us is over-specification." "... But if you want to have full flexibility on what you do is you are leaving the ceiling there somewhere for the future connections for water, medical gas etc., just in case you ever need. Again, one way to get flexibility is by over-specification." "Initially it could be seen as over-specification but if you just take a bedroom for example and you put facilities into that bedroom which means it could be used as a treatment room and a consulting room …you would be putting stuff in there that …might not be needed … if it was a bedroom but if that room then changes within 3 years' time, you would have a cost saving then because you do not have to go in and retrofit it."
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. "[We] develop a series of standards for repeatable designs and they are being [put]… into a Revit model and we are adding… non-graphical data to them as well." "I think the impact of futureproofing is linearly aligned to over-specification, but I also think… a [means to] mitigation… is around standardization. If you can standardize on products, then you can bring the price down". "We need to design a room that caters for these requirements in more general terms. So what we have done is to try and make a business case where you can have that room with that level of flexibility and still save money… by having the efficiency of a repeatable design, by having the efficiency of buying the same components in these rooms, you obviously have a procurement saving. So actually, rather than saving money by cutting area why don't we save money by having a common design and a common procurement process.

4.2 Explication of Context

After scrutinizing the sequence of events, we turn to the contextual conditions that are present when decision-makers engage in futureproofing talks (Table III, Step 2). Two conditions were identified in our futureproofing configuration model.

Condition #1 Capital targets versus whole-life targets: This condition originated in the relationship between the Government's policy directives and the service's performance. The service's delivery performance aimed to meet the 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]". Conversely, 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, was identified as an enabling condition for futureproofing. Similar observations regarding the exclusion of operations from projects is evidenced in the generic project lifecycle (concept to execution and decommissioning), where the operations phase is largely omitted [55]. A Managing Director for a consulting firm explains the rationale in a PPP-type contract: “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!”.

Condition #2 Tight project brief versus loosely-defined project brief: This condition related to the competing benefits of a tight versus loosely-defined project brief from the outset of the business case. Where the project brief was tightly focused, futureproofing solutions that were proposed by the supply chain were rejected. In contrast, projects that successfully implemented ROR in their development phase adopted a more loosely-defined project brief. The project brief did not freeze prior to entering the 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. Terminal 5 “last responsible moment”) [44]. An example of such an approach was outlined by the Sector Director of a consulting firm: “Futureproofing should really come from designing a building such as the [Project N] Hospital which was allowed fast-track construction. It was designed … not knowing were the departments will be, so it ended up with having huge floor plates, ducts on a regular basis and you could do what you like”.
On another example, the team challenged the brief and incorporated requirements for flexibility, in line with a ROR approach of focusing on the future requirements of the infrastructure. This would

not have been possible if delivery had been constrained by a tight brief. A Program Director justified this mindset of design flexibility: “What we've done is to extend our brief to say that we must have a room, that yes, it is cheap to build but if it is more expensive to run or it does not provide flexibility in the future then actually we have not achieved our goal”.

4.3 Explication of Causal Mechanisms

Various causal mechanisms were tested (Table III, Step 3) against the aforementioned events to examine how ROR was employed by decision-makers. The four causal mechanisms identified were clustered into two categories according to their powers to influence a design outcome towards futureproofing.

Effective mechanisms

In projects where the ROR approach was followed, futureproofing was implemented effectively, and two change mechanisms can be described:

Change mechanism #1 – Iteration between problem, design and solution spaces: Not freezing the project brief (condition #2) before the design solution reached the required maturity enabled an iterative loop between problem and solution space. These iterations resulted in both spaces being continually informed as the project matured, with feedback into the design space allowing solutions to develop and to be checked against the latest set of requirements. Principal and agent talked through possible options that were facilitated by the interplay of sacrificial systems, over-engineered systems and repeatable standardized systems (Table VI).

Through this mechanism, the teams enacted ROR, which resulted in numerous future interconnected design options being assembled. The outcome was a solution space which included options that satisfied the mature set of current and future requirements developed in the problem space. A number of options that could become plausible solutions were generated here but it was not determined at this point which of these candidate options, if any, would be implemented.

Change mechanism #2 – Making the case for affordability: In a ROR approach, the outcome of the second mechanism 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 (Outside view). A Director of Design for a major contractor explained this approach of going back and forth between past and new projects to inform the design approach: "Me, I would always spend time reading the business case … what is different about [Project A] as compared with [past Project B]?".

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 thinking is justified in the business case with reference to independent verification of results (e.g. more patients can be admitted). A Managing Director explained: "The concept of payment-by-results … implies that the only way that you afford anything …[is] by saying 'I am going to put more patients through'".

According to the interviewees, financial issues could stall approval and funding of a potential futureproof development. The dominant view was that budgets on a potential development were often already under financial pressure and thus clients would not decide on futureproofing design options unless these were perceived as affordable and profitable. Decision-makers compared past projects' affordability (Outside view) to inform their ROR thinking and to verify the viability of the proposed solution. However, this approach had salient weaknesses, which will now be discussed.

Ineffective mechanisms

In the case where changes were not implemented and the initial problem of failing to implement futureproofing was sustained, two problem mechanisms were identified: *Bounded thinking on future requirements*, and *Motivational gap*. While these mechanisms could be influenced by external constraints, the findings suggested factors internal to the decision-makers, which can be understood as emerging from their agentic capabilities notwithstanding structural contexts [39].

Problem mechanism #1 – Bounded thinking on future requirements: This mechanism draws on bounded rationality [56]. 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". Unfortunately, this solution might be far from optimal. The interviewees alluded to the complexity of the problem, as a Development Director argued*:* "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". The interviewee recognizes the complex, interconnected nature of ROR and the bounded nature of thinking in decision-making, suggesting that during futureproofing talks, the project teams did not adequately address the complexity of future requirements. A Program Manager for NHS estate emphasized: "I do not think we do it in detail" – a reference to simplification of thinking processes and a failure to employ ROR, leading to a focus on current requirements at the expense of future needs. The interviewees explicated uncertainty in two ways: uncertainty of outcomes and uncertainty over the meaning and value of futureproofing. Decision-makers acknowledged their limited cognition - what a Sector Director referred to as "insufficient thinking".

Problem mechanism #2 – Motivational gap: The causal powers of this mechanism stem 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 action does not occur [57]. The interviewees highlighted the difficulty of implementing futureproofing plans due to the different project values espoused by different agents in construction projects. According to a Managing Director and owner of an architectural practice, the primary contractor agents who usually lead the development process lacked personal commitment to futureproofing, while he and his team tried to push agendas such as sustainability and futureproofing: "But the truth is, those end up being words in a presentation to win the job and then after that the contractor is not interested. It is very frustrating".

In health estate projects, the decision-makers may be Tier 1 contractors to whom designers are often subcontracted. 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 absence of motivation from the more powerful decision-makers affect other actors in the construction project, as shown by the "frustration" mentioned in the previous quotation. The motivational gap led to frustration and, ultimately, a suboptimal solution. The reference to affect (emotion) demonstrates that emotions can also function as mechanisms for guiding and stopping information search within a ROR approach in futureproofing talks.

5 Discussion

This study addressed the question: "How do futureproofing decisions develop in informal futureproofing talks among clients and supply chain actors in complex infrastructure projects?". We focused on normative explanations which are supported by ROR. We developed a processual model and identified causal social mechanisms and contextual conditions that can enact or block the evolution of futureproofing within a development process. We showed that decision-makers apply ROR in the development process of health estate projects. Thus, our research builds on [11], where the authors probed the question of whether managers implement ROR and its requirements. In addition, the findings also offer additional evidence for the recognition that futureproofing is important for the long-term sustainability of construction projects [2], [4], [13].

Our findings synthesize and conceptualize earlier insights on iterative design thinking [58], affordability [3], [4], bounded rationality [59], and motivational gaps [43], [44] as causal mechanisms for futureproofing talks and thus ROR. This offers a novel contribution, addressing the gaps in the literature regarding the causal powers of each of these mechanisms and their interrelationships. We have shown how these mechanisms act transfactually, and how their actualization may be contingent on other mechanisms. A combination of conditions and causal mechanisms (not of all which we know) determine whether a system will be futureproof. Unlike other theoretical models which examine which mechanism might prevail over another, our model suggests it is the configuration of conditions and mechanisms that *in aggregate* will lead to a futureproof outcome. Fig. 2 shows the causal paths identified.

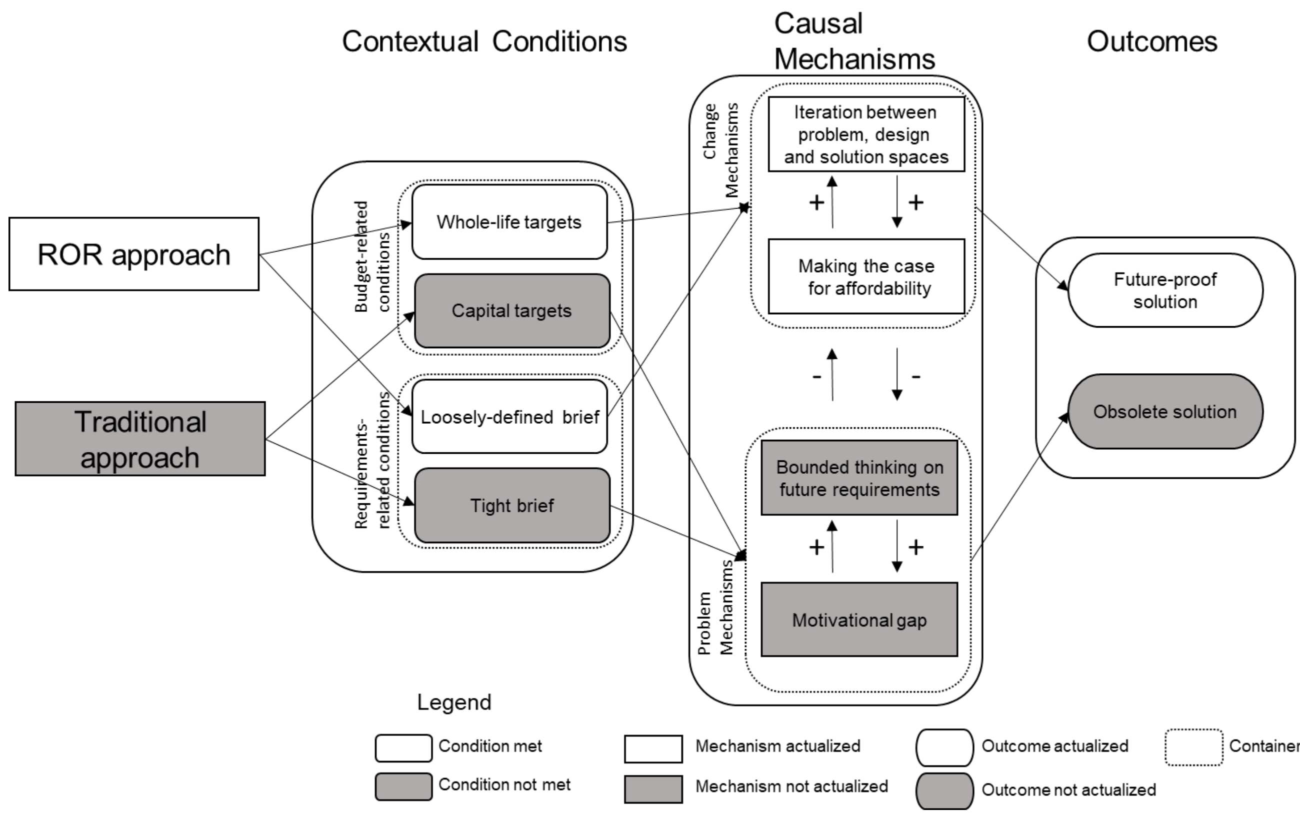

Fig. 2. Snapshot of configuration model resulting to a futureproof solution

5.1 Theoretical Implications

In project studies, there is a consistent and established body of knowledge emphasizing the importance of having all relevant details and information, so all key decisions can be taken before the project starts. Morris [60] asserts the importance of a detailed front-end to projects, Merrow [61] stresses that design needs to be completed to the point that execution can proceed without changes. This body of knowledge argues the importance of early completion of detailed design for the successful delivery of projects in terms of achieving cost-time-quality objectives (the classical iron triangle). However, the key insight and novelty of our research is that, while early finalization of detailed design might contribute to achievement of the short-term success of the iron triangle, this comes at the expense of missing the larger target of achieving a successful, long-term, futureproof infrastructure. ROR can support decision makers in planning and delivering infrastructure which is resilient across its life-cycle.

Our study offers four broad theoretical implications related to ROR. First, prior to our study, there have been few attempts to formulate perspectives that allow the simultaneous study of multiple causes of an inadequate development process [19], [28], [62]. In addition, few studies have shown that decision-makers apply the logic of real options in project settings [4], [16], [43]. Our configurational perspective recognizes: (i) the inherent complexity of futureproofing talks and the value of using mechanisms to uncover their complexity; (ii) the importance of contextual conditions surrounding those mechanisms; and (iii) the need for an analytical lens (i.e. ROR) for making sense of both. Regarding the role of contextual conditions in the configurational model, we view these as static in the short-term (during futureproofing talks), but dynamic over the long-term (the lifecycle of the infrastructure). Table VII summarizes the social causal mechanisms that are available in the existing literature, their contextual conditions and the potential outcomes they lead to.

Table VII List of social causal mechanisms, their contextual conditions and potential outcomes

Reference	Causal mechanisms	Contextual conditions	Outcome
[43]	Common vision by decision-makers	Project coalition; Strong Board involvement	Non-futureproofed project
[44]	Clear client strategic vision	Cooperation between parties	Futureproofed project
[4]	Bargaining power	Flat governance structure; Discussion facilitator	Non-futureproofed project
[45]	Utility maximization; Bounded rationality	Intentional choice architecture	Futureproofed project
[63]	Asymmetries of power	Ambitious targets for the deployment of new technologies; Regulations favoring collective solutions	Futureproofed project
[3], [14], [25]–[28]	Cognate error (rework)	Funding sources; Delivery strategies; Digitalization; and Asset management	Futureproofed project
[21]–[24]	Optimism bias; Strategic misrepresentation	Uniqueness; Competitive context	Non-futureproofed project
This paper	Iterative design thinking; Making the case for affordability	Whole-life targets; Loosely-defined brief	Futureproofed project
This paper	Bounded thinking on future requirements; Motivational gap	Capital targets; Tight brief	Non-futureproofed project

Second, ROR is a paradigm that can improve the planning and delivery of projects. Other schools include interactive planning [64], wave planning [65], future perfect thinking [66], systems thinking [67], design thinking [68], and actor-network theory [69]. Each school has several different interpretations and there are some overlaps between the schools. These schools cannot be treated like a series of well-defined independent silos but more like an artist's painting palette where the original color blurs in a beautiful mix of shades. Having this caveat in mind, Table VIII (appendix) highlights the key distinctive elements of each school, as presented in one of its most relevant papers. From this comparison, it is clear how ROR is an appropriate framework to support the decision-making of managers. ROR is particularly appropriate for strategic decisions with long term impacts, such as the kinds of decisions in the UK healthcare sector analyzed in this paper.

Third, our research acknowledges the ambiguity of the notion of futureproofing. The configurational perspective highlights how different interpretations of futureproofing (e.g. tick-box exercise versus flexible design) reflect different constellations of mechanisms and contextual conditions. Where these facilitated application of ROR by the decision-makers, the result was futureproof outcomes

Lastly, we consider the trade-off between over-engineered systems, that allow for flexibility, with economies of scale (doing an infrastructure of large size to reduce costs) and economies of multiples (building several identical infrastructures to achieve economies from mass production). In the power sector, the literature suggests modularization as a strategy to deal with this trade-off [70]. Some work has investigated how the combination of real options and modularization generate flexibility in the construction and operation of nuclear power plants [71]–[73] or energy storage [74]. However similar analyses in the wider context of complex infrastructure are scarce and therefore this is an opportunity for future research.

5.2 Managerial Implications

ROR research asserts that 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 causal mechanisms and their contextual conditions. Front-end decisions on embedding flexibility [17], [75] 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.

Our recommendations complement prior managerial recommendations of a structural nature [4], on adopting flat governance structures and futureproofing champions and [13] on developing a process management lifecycle performance measurement system for PPPs. 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.
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 accounting for the “process perspective” [13]. Thus, construction capital investments could bring futureproofing higher up 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 (problem mechanism #1) and absence of personal commitment to futureproofing principles (problem mechanism #2) 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 (and ideally share) 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 [13], [15]. Beside the cost implications, the database should report the causes of change. Slaughter's [75] types of changes according to function, capacity and flow 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 [8] could have averted or minimized the impact of these changes.

6 CONCLUSION

Complex infrastructure, including hospitals, universities and nuclear power plants, has a long operating life, spanning decades or centuries, therefore exact forecasts and scenarios analyses are not feasible. Uncertainty need to be managed across their long and unpredictable lifecycle. Common performance measures enacted by best practices suggested in project studies focus on reducing capital cost and pay less attention to lifecycle performance, leading decision-makers to solutions that, in the long term, are sub-optimal. The key contribution of our study is to examine the potential of ROR for moving beyond the short-term success of the iron triangle and towards achieving long-term successful infrastructure. In particular, we propose that ROR is an ideal framework to futureproof complex infrastructure. ROR enables decision-makers to deal with critical dilemmas such as the trade-offs between flexibility and commitment. Our paper provides two original contributions to knowledge on ROR and infrastructure.

First, prior research has applied ROR in complex infrastructure development only in terms of forms of organizing (i.e. governance structures) to deliver futureproof solutions [4], and in terms of how infrastructure systems can accommodate flexibility [17]. Remarkably, the literature has paid far less attention at the level of individual agency and decision-making. Our study expands the discussion from organizational structures and systems to include individuals. We established the significance of the individual decision-making process and showed that using ROR is an ideal approach for operationalizing futureproofing in the developing process. Ultimately, we advocate that decision-makers should employ ROR in the early stages of infrastructure development.

Second, prior literature can be critiqued in explaining infrastructure cost overruns via accounts of human actions that are either under- or over-socialized. For instance, optimism bias [24] arguments offer under-socialized conceptions of human behavior because they tend to ignore social influences. Complexity arguments [34] may be considered over-socialized conceptions in their assumption that human action is primarily determined by social influences. We provide a new process model that adopts a configurational perspective of ROR and accounts for influences both internal (i.e. mechanisms) and external (i.e. conditions) to the individual. The model articulates the multiple paths by which futureproofing configurations materialize, enabling understanding of the causal mechanisms and contextual conditions that, in aggregate, lead to futureproof solutions.

The paper paves the way to several future topics for research: we recommend five possible developments that we believe are needed. First, the granularity of our approach to causality was relatively high level, and we cannot claim to have discovered all relevant mechanisms of futureproofing. Further research could employ the configurational model to establish more mechanisms and conditions both horizontally (i.e. at the same level as our mechanisms) and vertically [38]. Second, project research faces the deep challenge of borrowing theories from other disciplines (in this case, the CMO model) without a necessary methodological evaluation. Our research highlights future developmental trajectories (e.g. futureproofed building), and past pathways (social causal mechanisms) to an observed outcome. However, given the inherent complexity and context that characterizes these projects [33], we must be careful in the generalization of our results. For instance, cultural or legislative elements could play a key role. This may represent a limitation of importing such a theory into complex project settings. Third, future research could consider the microfoundations view [76], [77], which provides a comprehensive framework for understanding the role of individuals along with process and organizational structures. Fourth, follow up research could focus on robustness analysis [78] and hindcasting. These are approaches for assessing the merit of decisions taken in situations of uncertainty. These decisions can be scrutinized according to the effects that they trigger (including if they were expected or not) and the potential for flexibility in future decisions. Finally, the configurations identified above are not exhaustive and other configurations are likely to exist. There is merit in assessing the mechanisms and conditions that obtain in other domains such as transport, water or other infrastructure. We believe that by specifying the causal mechanisms and contextual conditions of the individual decision-making process, our research provides guidance for organizations and decision-makers seeking to navigate the difficult and challenging process of futureproofing complex infrastructure projects.

Disclosure statement

No potential conflict of interest is reported by the authors.

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Table VIII Key elements of each school as described in the reference papers

	Real Options Reasoning	Interactive planning	Wave planning	Future perfect thinking	Systems thinking	Design thinking	Actor-network theory
Key stakeholders	Managers and decision-makers	Organizations	Project team members	Project team members, planners in particular	Project team's member, manager in particular	Very comprehensive approach involving internal and external stakeholders	Used by research to study the network of human and not-human in the project
Key elements	Managing the fundamental decision asymmetry to take a future decision (e.g., invest) only if it's beneficial to the decision maker, but not otherwise [p. 43] Using flexibility to address macro-risks and uncertainties Logical tool or rhetorical device for creating or keeping options open and exploiting them [p. 47]	Directed at creating the future. It is based on the belief that an organization's future depends at least as much on what it does between now and then, as on what is done to it [p. 3] Sensemaking of the "mess" where the organization is	Methodology for planning complex projects [p. 347] Explains how project management could be used to implement change projects [p. 347]	The forward-looking projection of ends is combined with a visualization of the means by which that projected future may be accomplished [p. 574] Creating a mentality of "best-for-project" connected to the "no-blame" culture [p. 577]	Consciously organized thinking using systems ideas [p. 45] Whole entity which can adapt and survive, within limits, in a changing environment [p. 49]. The whole entity 'more than the sum of its parts' [p. 50]	Structured process of exploration for ill-defined problems. A human-centered innovation process that emphasizes observation, collaboration, fast learning, visualization of ideas, rapid concept prototyping, and concurrent business analysis [p. 145] Aim to bring designers' principles, methods, and tools to management and business strategy [p. 145]	Stresses how an actor is defined by its relations: the thoughts, feelings and actions, even identity, of any actor (such as a project manager), are the result of the relations that actor can and does form with other entities, including nonhumans, such as computer systems, paperwork, offices, cars, charts, reports as well as humans [p. 275]
Dilemma(s) addressed	Commitment vs flexibility Competition vs cooperation	The design of a desirable present and the selection or invention of ways of approximating it as closely as possible [p. 3]	Balancing detailed and operative short-term planning with more high-level long-term strategic planning	How to make the uncertainty attached to the future something that can be dealt with in advance of it occurring [p. 574]	Several. This approach is very flexible	Several. This approach is very flexible	Show the limits of front-end and linear project planning not least front-end stakeholder analysis [p. 276]
Level of application	High level decisions about fundamental choices in the project	High level decisions to shape the future of an organization	Iterative shifting from high level goals to more iterative decisions and back	All levels. Stakeholders deal with the questions "What would they have to have done to achieve the outstanding performance across the demanding range of indicators to which they had committed?" [p. 577]	High level systemic view. Can be also above the single project (the hospital) when the system is intended as environment where the project is delivered (healthcare system)	All levels. It supports high level decisions along with the element of detail (such specific solutions in the design). However Recent developments in design thinking claim that it needs to move "upstream," where strategic decisions are made [p. 150]	All levels. Is a theoretical approach to the study of human-nonhuman relationships concerned with "the agency or active involvement of non-human 'things' in a social setting [p. 275]
Field of origin	Finance and Strategy	Organization studies	Project Management	Various social sciences	Various social and hard sciences	Product design	Sociology
Continuous vs discrete approach	Discrete. There are meeting to collectively evaluate the options	Discrete. There are meeting to collectively examine a series of key questions	Continuous across the delivery of the project	Continuous. It is a practice for everyday management [p. 575]	Can be both, ideally continuous	Uncertainty reduction strategy that can be achieved through a learning focused, hypothesis-driven approach; this learning associates abstract reasoning with action in order to launch a reflective conversation with the situation [p. 148]	Discrete. There are ad-hoc meetings, mostly lead by academics.
Ideal application	When the key drivers of real option value can be identified and synthesized conceptually even if options cannot be valued formally [p. 47]	Reshaping and redesign of organizations. Need to define / update the mission of an organization and its distinctive characteristics	Managing complex project management	For situations of high uncertainty[…], where most of the work is done at the planning stages of the project, to instill a vision of what the future "may" look like in order to create mental maps of how one might deal with variation if it occurs . [p. 575]	When dealing with a system, particularly if complex, that include tangible (hard) and intangible (soft) elements	In innovative contexts characterized by uncertainty and complexity [p. 144] Deals with ill-structured situations where the problem is not articulated and is considered a hypothesis where action stimulates thoughts to inspire better hypotheses [p. 150]	Novel re-assessment of managing in (project) complexity, especially when thinking and responding to stakeholder complexities and power relations [p. 275] Post-review of projects [p. 277] Enables researchers to be aware of emergent properties, unintended consequences and unpredictable behavior [p. 287]
Expected benefit	Better strategic choices, enhancing firm value and providing valuable management of risk. [p. 54]	Futureproofed organizations Long term improvement of organization performance	Ensuring you have identified the critical details in the upcoming work Make information more manageable for the team (the right information at the right time) Makes the long-term plan more manageable	Improving interorganizational collaboration [p. 575] New capabilities for organizations [p. 575] Improving project's KPIs	Provide a way of conceptualizing the social processes in which, in an organizational context, a particular group of people can conceptualize their world and hence the purposeful action they wish to undertake [p. 54].	Valuable for improving innovative outcomes, whether they are products, services, or strategies [p. 144] Improve the link between project and strategy [p. 146]	Describe how heterogeneous actors in the "living present" themselves attempted to register, respond to and stabilize project complexities, particularly the emergence of new relations and hence new actors. [p. 280]