Interorganizational Development of Flexible Capital Designs: The Case of Future-Proofing Infrastructure

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Abstract—**This mixed-methods study investigates a dilemma that interorganizational groups formed to develop long-lived capital assets invariably face at the project front end: either invest in flexible design structures that cope economically with change in requirements, this is design to evolve—at risk of the extra costs not paying off if the uncertainties fail to resolve favorably later on, or endorse cheaper but more rigid designs—at risk of higher adaptation costs if the uncertainties materialize in the future. Through an empirical study grounded in the British railway sector, we reveal that groups regularly engage in informal *future-proofing* discussions to address this dilemma. But faced with tight budgets and timescales as well as differing interests, the groups struggle to achieve consensus over the need for flexible designs. Through lab experiments and taking a flat governance structure as given, we unexpectedly find that an administrative device to facilitate multiparty future-proofing talks has limited impact on the outcomes. Hence, we argue that a collective action problem is central to interorganizational development of flexible capital designs. We conclude by discussing alternative structures to govern the project front end, and how to better exploit the value of flexible designs.**

Index Terms—**Collective action, design flexibility, evolvability, governance, infrastructure, projects.**

I. Introduction

EXPLORING the value of flexible design structures to manage the tension between efficiency and effectiveness is an enduring goal in the projects and development literatures and, thus, in the development of both new commercial products [2], [52], [55] and large engineering and infrastructure systems, the so-called capital projects [10], [12], [16], [18], [26], [37], [38]. Efficiency pertains to deliver projects on time and within budget, whereas effectiveness to ensure that the development process copes economically with change in the design requirements.

Flexible designs avoid premature lock-in into early commitments and, thus, mitigate the risks of schedule and budget overruns. Flexible designs can be achieved by modularizing designs [2], [52] or safeguarding integral designs [16], but physical constraints and technology can make it hard to develop affordable flexible capital designs notably for large infrastructure (e.g., transport and power systems, schools, hospitals). Hence, Gil and Tether [18] argue that in capital projects, design flexibility, and risk management practices, e.g., planning contingencies, project controls, risk registers, are complements.

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Complementarities notwithstanding empirical regularities suggest that risk management practices prevail in capital projects [18], [37], [38]. Noticing this, Lenfle and Loch [31] argue that project management practice in general puts too much emphasis on control and risk management to the detriment of flexibility.

However, in the case of infrastructure, capital projects create one-off arenas of collective action that unify under a higher order goal autonomous stakeholders all of which claim rights to directly influence high-order development decisions [19]. The independent stakeholders control interdependent resources, such as finance, land, and planning power. The higher order goal makes it tempting for the stakeholders to collaborate to advance their self-interests, but sharp disagreements are likely to ensue over the plans for achieving the goal. Complicating matters, these voluntary, consensus-oriented collaborations [20] are led by political coalitions and, thus, do not benefit from a unitary governing authority legitimized by government regulation or property rights. With limited time to seek congruence over a high-level plan due to externalities, such as rigid electoral calendars, the stakeholders engage in compromise seeking, and mutual-gains bargaining to get things done [20], [34]. These are traditional mechanisms employed in interest-based negotiations, but characteristic of ineffective collaborations [29].

This suggests that the one-off groups of autonomous stakeholders or principals formed to plan the new infrastructure do not benefit from many antecedents for effective collaboration including a prior positive history of working relationships and a collective identity [21], [39], and formal group-level plans and rules [30], [44], [46], [47]. Hence, attributing the lack of investment in flexible capital designs to ignorance and/or incompetence of the project managers is excessively reductionist.

This in turn leads to the core question motivating this study, that is, can we trace the difficulties to invest in flexible capital designs to inefficiencies in the development process and to the governance structure of the interorganizational groups formed to plan the capital projects?

To address these questions, we combine inductive case reasoning with lab experiments. First, we use an empirical study grounded in Britain's railway sector to explore the motivations and obstacles to develop flexible capital designs. We find that the new schemes are planned by groups of autonomous parties, which operate under no formal hierarchy, binding contracts, or authority of a systems integrator [5]. To address the tradeoffs between rigid versus flexible infrastructure designs, the groups engage in ad hoc "future-proofing" talks, but they invariably struggle to resolve their differences.

Taking the flat governance structure of the groups as given, we then use a lab experiment to investigate the impact of facilitating the future-proofing talks between principals with an administrative device. Interorganizational theory suggests that one antecedent of collaboration is the presence of a legitimate convener with credibility in multiple arenas touched by the problem to draw together autonomous stakeholders [21], and as said, group studies show that groups can be more effective in the presence of formal plans and rules. Hence, we expected that by adding a champion to facilitate the planning talks (so-called design-for-evolvability champion), the stakeholders would struggle less to achieve consensus.

Our lab results reveal no push back on efforts to formalize future-proofing talks, but unexpectedly do not reveal statistically significant impacts. These findings suggest a link between flat governance and the difficulties that the groups of heterogeneous and autonomous principals face to develop the flexible capital designs. Modifying the governance structure, we argue, is a prerequisite for the groups to exploit better the value of capital design flexibility.

We organize the remainder of this paper as follows. After reviewing the relevant literature, we explain our methods. In the analysis, we examine the design practices in Britain's railway sector and the results of the lab experiments. We then discuss the collective action problem central to the development of flexible capital designs, and conclude by addressing alternative governance structures for potentially facilitating the exploitation of capital design flexibility.

II. Background

Flexible designs can be produced through modular or near decomposable design structures [2], [49] or safeguarded integral design structures [16]. Design structures allocate the functions of a product to its components [55]. Modular designs break apart the interdependencies between functional components and, thus, have design options built-in that allow the design as a whole to evolve economically. Limited flexibility can also be designed in more integral design structures using design safeguards, this is built-in redundancies and spare capacity [16].

In commercial product development, flexible designs enable manufacturers to reuse the designs across projects and, thus, extend design longevity [52]. In capital projects, flexible designs also enable design reuse—Intel, for example, reuses designs for semiconductor fabrication facilities (fabs) to speed up new fab development and ramp up [17]. And importantly, flexible capital designs reduce the adaptation costs over the project time and then over the asset's operating life [18].

However, flexible design structures are not free [2], [16], [51]. Still de Neufville and Scholtes [10] contend that flexible designs lead to cheaper projects than integral designs because flexibility allows us to stagger the investment as the uncertainties resolve favorably. This is true, but if the uncertainties never resolve favorably, investing in a rigid design commensurate with the upfront requirements would be more economical even if riskier; furthermore, investing in options to switch operating regimes requires extra expenditure. Hence, design flexibility is like buying an insurance policy [10]. There is no free lunch, and mitigating the risks of high adaptation costs through flexible design structures involves an extra cost upfront.

The tension between short-term savings associated with rigid designs versus the potential long-term gains of built-in flexibility makes it crucial to evaluate the payoffs of flexible designs. To this purpose, scholars have used real options theory [6], [7], [10], [53]. A real option gives its "buyer" the ability to postpone an investment, while leaving open the option to invest under uncertainty ("exercise" the option). Likewise, flexible capital designs have built-in options that can be exercised if the future resolves favorably. Hence, flexible designs enable to benefit from upside scenarios under uncertainty, while limiting the losses on the downside.

The uptake of the real options approach has, however, been slow due to difficulties in ensuring the tractability of real options models, in making reliable numeric assumptions, and in eliminating endogenous processes [27]. An alternative research vein, real options reasoning, derives qualitative statements from real options theory and asks managers to specify their level of agreement before setting priorities and allocating resources [36]. This approach has been explored by organizations to inform investment on new technologies and R&D, but rarely to evaluate capital design flexibility.

Extraordinarily, extant literature seldom discusses *who actually pays* for the upfront cost of flexible designs. Real options theory downplays this issue as it assumes that this cost is marginal [53]. Likewise, in new product development, the payoffs of modular designs largely outweigh the extra costs incurred upfront [2].

However, in infrastructure projects, flexible designs require substantial investment upfront [16]. Building a tunnel to safeguard an airport expansion or designing a dual-purpose stadium (to host athletics and football) is not cheap. The extra investment may be the right decision considering the life-cycle costs, but still will not happen if it is deemed unaffordable. This problem is amplified in infrastructure projects, wherein the higher order development decisions are not up to a unitary organization [26], but rather are the outcome of multiparty negotiations among stakeholders with differing interests, preferences, beliefs, and planning horizons [20], [34].

All in all, our understanding is scarce as to how a group of autonomous stakeholders decides on capital design flexibility. Gil and Tether [18] argue that uncertainty, which makes flexibility more valuable, paradoxically puts off the groups from investing in flexibility because it precludes the development of a common vision. Since options logic is intuitive, we ask: can the difficulties in developing flexible capital designs be traced instead to 1) process inefficiencies; and 2) the governance structure? These two questions motivate this study.

III. Research Methods

We adopted mixed-methods to further our understanding of how investments in design flexibility play out in capital projects. Through an empirical study, we first reveal how interorganizational groups use options logic intuitively to frame "future-proofing" discussions. We then use a two-group controlled

TABLE I
SUMMARY OF THE SAMPLED RAILWAY DEVELOPMENT PROJECTS

Project	Warrington	Reading	Salford
Scope	Build a new rail bypass (chord) to connect two existing freight lines	Build new station platforms and concourses; improve the layout	Modernize the station platforms and station building
Goal	Release land to facilitate access to city waterfront	Increase the capacity of a critical railway station	Eliminate overcrowding on the platform
Anticipated final cost (cash prices)	~£15 million	~£150 million (station building); overall project costs ~£850 million	~£12 million
Front-end planning	~2 years (October 2008–December 2010)	~2 years (February 2006–January 2008)	~1.5 years (May 2009–September 2010)
Estimated project duration	Six years (2008–2014)	Nine years (2006–2015)	Five years (2009–2014)
Key participants in the front-end planning talks	NR, local council, freight operating companies, public regeneration agency	Central government/Department for Transport (DfT), local council, NR, property developers, train operating companies	University, NR, train operating companies, local council, DfT, regeneration and transport agencies
Sense of urgency	Debatable *Low for NR, high for the Local Council*	High across the board *Urgent need to resolve major capacity bottleneck*	High across the board *Closure of station imminent due to hazards*

experiment to test whether introducing an administrative device to facilitate future-proofing discussions leads to more efficient discussions, increases participants' satisfaction with the process, and changes the outcomes.

Lab experiments complement observational studies as they allow for investigating how changes in specific variables influence the participants' behaviors and outcomes [9], [43]. Lab experiments also allow us to control for confounders that would compromise internal validity such as contextual variables, and to create lab conditions that are replicable to test empirical propositions. Studies of the correspondence between experimental and observational findings have refuted claims that lab experiments lack external validity [1], and show that lab studies can simulate effectively critical features of group decision making [14].

For this mixed-methods study, lab experiments were important to investigate if the observed empirical regularities—the tussles over flexible capital designs—could be attributed to the informal nature of the future-proofing talks. The lab experiments allowed us to control for the observed flat governance of the interorganizational groups, which we took as given.

We grounded our field study and subsequent lab work in the British railway sector. The tension between designing a flexible scheme versus progressing with a rigid one is central to projects to develop new long-lived railway schemes. Railways are also an empirically relevant sector attending to the sheer scale of rail work underway around the world.

The UK case is particularly interesting because 70% of its railway infrastructure is around 100 years old [8]. The Victorian railway infrastructure was designed to evolve, but now it operates at full capacity in critical parts and, thus, Network Rail (NR)—the public monopolist that owns the UK's railway infrastructure—spends £2billion yearly in capital projects. In complicating matters, the government is asking NR to deliver more for less. "Hard times, great expectations," said the NR's chief executive in 2012 about this mismatch.

To explore how groups formed to deliver new railway schemes negotiate between short-term affordability and long-term adaptability, we formed a diverse and polarized sample as recommended for process-focused inductive studies [48]. Our sample varies in the role of NR and in the project size. Specifically, Warrington is a £15 million scheme to develop a new rail chord in which a local council plays the promoter role and NR the supplier role. Reading is a very large £850 million scheme to revitalize a national railway junction funded by the UK government and, thus, NR acts both as the government's agent and project supplier, and Salford is a £12 million station redevelopment also funded by the UK government (see Table I).

Data collection involved semistructured interviews, two workshops, analysis of archival documents, and attendance of eight project meetings. Our key informant was a senior NR Program Manager who provided the second author access to the NR Infrastructure Division, restricted access to the intranet, and introductions to key staff members. Between February 2010 and August 2011, we conducted 34 one-on-one meetings with staff from NR (e.g., project manager, engineer, risk manager, commercial sponsor[1]), project clients, and other design participants identified through a snowball effect [4]. We also organized two 2h-long workshops focused on design flexibility in capital projects, each attended by eight employees of NR. We recorded and transcribed the interviews and the workshops, and complemented this data with hand-written notes taken from informal chats entertained by the second author during a placement at the NR Infrastructure Division.

We triangulated the interview findings with information in design briefs, meeting minutes, public consultation reports, NR corporate information, project procedures, and threads of e-mail exchanges archived on NR's intranet. Other documents were retrieved from the websites of the local councils and public agencies, and from the trade press, e.g., New Civil Engineer and local newspapers. After developing focused narratives for each case, we undertook cross-case analysis and played case data against the development and project literatures.

[1]Commercial sponsors lead the negotiations between NR and business partners, such as private train operators to satisfy the interests of the partners without compromising the NR's commercial interests.

As we iterated between case data and theory, a link surfaced between the lack of investment in design flexibility and the struggles to bridge differences over the perceived value of design future proofing. Given the diversity of our sample, the empirical regularities suggested that the struggles were unrelated to project size or the promoter's preferences. Rather, we traced the problem to the distribution of decision rights in development. We also conjectured that process inefficiencies hampered investments in design flexibility.

Taking the observed flat governance as given, we then undertook a lab study to test the hypotheses that using a formal device to facilitate the future-proofing discussions would: 1) increase the efficiency of development; 2) facilitate group collaboration and, thus, increase the participants' satisfaction with the process; and 3) lead to more flexible designs.

One could argue that the expected positive effect of introducing a formal organizational brokering mechanism to facilitate the multiparty future-proofing talks would make it unnecessary to test for it. But the testing was important to establish a factual base about the significance of the effect. It was also unclear if group heterogeneity and the uncertain payoffs of design flexibility could counteract the tendency for groups that operate under stable environments to perform better with more formal devices [35].

Specifically, the lab experiment simulated the front-end planning of a new railway project and, thus, the decision-making process to set the design requirements and the budget. We used the Salford case to inform the experiment because it was focused and well documented, and although a small project, the future-proofing discussions turned out to be quite difficult. To test our hypotheses, we conceived a "design-for-evolvability" device to offer a formal structure to the future-proofing talks. A "design-for-evolvability champion," a role created as a coordination mechanism [3], helped the experimental groups to use the administrative device.

We assembled 20 groups of graduate-standing students including 11 experimental and nine control groups. Each control group included six roles[2]—three NR officials (engineer, project manager, commercial sponsor), a regional regeneration agency official, a university official, and a representative of the private station operator. The control groups were left to their own devices to resolve the front-end planning, whereas the Design for Evolvability champion facilitated the discussions of the experimental groups. To train the champions, we gave them a 2-h tutorial and handed out a set of reading materials. Each participant received information about their own role, the parent organization, objective function, and the negotiable pool of resources available to plan the new scheme. Participants had a week to prepare for a 3-h meeting during which the groups were tasked to resolve the project scope and corresponding budget; each group had one week to submit a meeting minute and a project plan. We provide additional details about the lab setup before analyzing the results.

The fieldwork suggested that many participants in the front-end planning had no experience in railway projects at all. Many were pulled into project planning meetings simply because of their elected or administrative roles. Our lab experiments reproduced this situation. Hence, the members of the groups had limited acquaintanceship and group membership was asymmetric, that is NR had more people attending the meetings than other parties. To manage the groups, we first let the students with a technical and management background take the NR roles, and then, we randomly allocated the remaining students to the other roles. The students' backgrounds were diverse ranging from more mature MBA students to younger M.Sc. students; the gender representation was balanced.

We now turn to analyze the empirical findings and then the lab experiments.

[2]In some cases, two students shared a role.

IV. Analysis

A. *Interorganizational Development of Flexible Capital Designs: An Inefficient Process*

Our empirical findings reveal that the groups formed to plan new railway schemes are left to their own devices for decisions to invest in design flexibility. The design options are seldom technically complex to design in, but their capital costs are not negligible. To address the tradeoffs, the groups frequently use options logic intuitively, but they invariably struggle to achieve consensus around who should pay for design flexibility; as one NR respondent put it, "It's among the easiest things to identify what we might do to future proof," the hardest is to say "who's going to pay for that?" Table II illustrates the analysis that follows.

The Warrington scheme is telling of the difficult tradeoffs that the groups face when choosing whether or not to future proof the designs. For the council, the £15 million scheme was vital to regenerate the city's waterfront. If the scheme went ahead, the railway assets that cut off pedestrian access to the waterfront could be demolished and the land sold for development. To succeed, the council needed to move quickly since the party likely to win the incoming national elections had pledged to shut down the funder, a regional regeneration agency. But the scheme was not a priority for NR who framed the council as the client:

> "It's our job to present the information unbiased. We've to clearly say: "look, these are your options" . . . .they [the Council] have to make their own decisions . . . .although they rely quite heavily on our advice the accountability is with them, the funder [NR Project manager]."

To the dismay of the council, the NR local team insisted that the design needed to be future proofed for the modernization of the line—"the scheme would not survive any network change consultation otherwise," explained the senior route planner. The cash-strapped council hit back, and challenged the NR's design requirements. One Councilor said:

> " . . . why do we need double track if the traffic is not that heavy? and is it worth spending money at all making provisions for electrification? I need to ask these questions."

The Council's demands for NR to go ahead with a rigid scheme fell flat, however. The Council's efforts to entice the

TABLE II
SUMMARY OF EVIDENCE ON FUTURE-PROOFING TALKS: CATEGORICAL AND QUALITATIVE

Project	Warrington	Reading	Salford
Salient future-proofing talks (design options)	Future-proof the design to reduce the costs for electrifying and increasing the rail gauge	Future-proof the design to reduce the costs for further expanding the station	Future-proof the design to reduce the costs for adding a 3rd platform and a landmark building
Option types	Switch operational regime	Stage project delivery	Grow asset capacity
Proponent	NR technical division	Local Council	Multiple design claimants
Upfront capital cost of the design options (cash prices)	~£0.5 million	~£1 million	~£3 million
	(~3.3% increase to the overall project budget)	(~0.7% increase to the station building budget; ~0.15% increase to the project budget)	(~25% increase to the overall project budget)
Long-term value of the design options	Debatable	High (just for the Council)	Unclear to all parties
	The Council argues that the option is unnecessary, but NR fundamentally disagrees	*The option will make the surrounding area more attractive to private developers*	*Hard to predict if and when a 3rd platform and landmark building will be added*
Converging the different perspectives	Difficult	Difficult	Difficult
	NR asked the local Council to pay for the option, but the Council says it cannot afford	The Council asked NR to pay for the option, but NR insisted it was outside the project scope	The government grant for small stations does not cover railway line enhancements
	I cannot understand why NR is asking that we [Council] have to pay for allowing future electrification [Councillor]	*It took a lot of effort [to reject Council's ideas] and made us look pretty poor* [NR program manager]	*The rail industry is—quite clearly—incredibly complicated and bureaucratic* [Regeneration agency]
Outcome of future-proofing discussions	Impasse	Flexible design endorsed	Rigid design endorsed
	Scheme stalled before the parties had time to resolve their differences	NR agreed to fund the option after Council threatened to exercise power of veto	Rigid scheme forged ahead as no one stepped in to finance the design options

freight operators to chip in (the scheme would cut 30 min of their journey time) also turned into nothing. As the negotiations for the scheme dragged, the funder was shut down, and the Council moved the scheme to the back burner; it also became cynical of the development process—"cannot see it working," said the leading Councilor.

Likewise, the development of the Reading scheme was intertwined with inefficient discussions about who would pay for design flexibility. NR, the government, and the local authorities shared the goal, and agreed on the urgency of the £850 million scheme. But the Council insisted that the station building should be future proofed to catalyze a £400 million investment from a private developer in the area surrounding the station. The NR team pushed back after it estimated that future proofing would push capital costs up £1 million. In complicating matters the private developer put its investment plans on hold after the 2008 financial crisis.

Unlike the Warrington case, the cash-strapped Reading Council held sway and threatened to veto the NR planning application for the station building. Concerned with the backlash if the scheme derailed, especially since the costs to design in the future-proofing provisions were marginal relative to the project budget, NR caved in. The NR Program Manager said:

> "This Councillor, a very strong character, was probably the reason why these ideas went forward. I mean, NR's view is to do what we've been asked to; as an organization, we don't really care about the streets of Reading, and DfT, well, that's not their game."

Importantly, our findings show that decisions to future proof are equally difficult in small schemes. In the Salford case, everyone agreed on the urgency of the scheme, but the government's grant ruled out finance to railway infrastructure. The planning agencies insisted that the design should safeguard for a new platform and a landmark station building, and the neighboring University even insisted that a third platform should be built to align the project with its £100 million campus expansion program. In contrast, the private station operator whose franchise was going to expire in 2014 was reluctant to endorse any major building works.

Constrained by the rules of the game, the group scrambled to agree on whether to build the third platform (and increase the budget several fold), safeguard it (and increase the budget around 25%), or ditch design future proofing. Exasperated by the inefficient future-proofing talks, the NR Project Manager said "sooner or later, we'll have to put something in there." After two years of talks and facing a stalemate scenario, the parties ruled out any investment in future proofing. The Project Manager said: "the trick is working out a realistic scenario in ten years' time; and sometimes it comes down to crystal gazing your assumptions."

We next build on these empirical regularities to formulate hypotheses as to the impacts of using an "integrative device" [28] to facilitate future-proofing talks.

B. Conjecturing the Impacts of Formalizing Future-Proofing Discussions

All in all, our findings show that the groups formed at the front-end planning of a new infrastructure project invariably engage in bargaining over future proofing. To frame the discussions, they deploy options logic. Our findings are unclear if the project budgets are as tight as the actors say they are. In the Reading case, for example, the budget had slack and NR caved in to avoid an impasse. This was a large railway project that was unfolding under the public eye, and arguably the Council reckoned that playing hard ball would payoff.

The findings also suggest that in such an informal arena for bargaining, the personalities of those attending the meetings and their beliefs influence directly the outcomes. As one NR engineer put it: "I future proof. That's me doing what I believe is right . . . .but that doesn't play into the corporate vision; perhaps I'm wasting company money." The same respondent felt that the planning process rewarded those "who get it wrong, who fail to plan for the future." But another respondent counter argued that a line needed to be drawn in the sand to prevent wasteful investments driven by "wonderful utopias of modernizing unprofitable lines."

As uncertainty is high as to if and when design flexibility pays off (in contrast to the certain upfront costs), the problem boils down to agreeing who pays for the extra costs. To complicate matters, the formal governance over decision making is flat as the parties are legally independent, and no legal contracts exist between them to govern the planning stage.

When groups work in stable environments, formal devices, i.e., preplans, controls, communication nets, improve collaboration [30], [44]. The decisions to design or not flexibility happen in a stable environment since group membership is stable. The technological knowledge is also not changing rapidly, and we did not observe antagonistic goals that could cause sharp conflicts. If the resources were plenty, future-proofing decisions would be consensual.

This hypothetically suggests that a device to formalize the future-proofing discussions could make development more efficient and satisfying for the participants. The observed use of intuitive options logic suggests the opportunity to adopt real options, and the juxtaposition of heterogeneous stakeholders with a cash-strapped project environment suggests the opportunity to use formal real options reasoning [36]. We thus hypothesize as follows.

1) *H1:* Introducing a formal framework based on real options reasoning allows the group participants to undertake future-proofing discussions more efficiently;
2) *H2:* Introducing a formal framework based on real options reasoning allows the group participants to gain greater satisfaction in future-proofing discussions.

Our analysis also suggests that the groups invariably struggle to design in flexibility. In Salford, no one wanted to pay for the substantial capital cost of design flexibility—under urgency to progress, the group settled on a rigid design. In contrast, the capital cost of flexibility was marginal in Reading—still, the Council only won the fight for a flexible design after a credible threat to use the power of veto and provoke a rumpus; and in Warrington, albeit the marginal capital costs of design flexibility, the parties fell into a stalemate situation.

All in all, these findings suggest that in an informal setting constrained by tight budgets and timescales juxtaposed with high stakes stemming from the longevity of the future infrastructure it is hard to win an argument that a flexible design creates more long-term value than a rigid cheaper design. The attractiveness of rigid designs arguably gets amplified because many payoffs are intergenerational and not bounded to the project time [16].

These findings corroborate claims that intuitive decision making is susceptible to pitfalls due to cognitive biases and organizational pressure [33]. Group cooperation is also more difficult when accountability is limited [43], and people lack formal processes to overcome mutual ignorance [13], [22]. In stable environments, however, formal devices help people understand better what keeps them apart [30]. Formal devices also link decisions to those responsible for making them and, thus, improve the accountability for the group outcomes [41].

Despite difficulties in achieving consensus, each group can only endorse one single design for the scheme which all group members will share in use. Hence, to get things done, group participants have no alternative left but to seek compromises and bargain, this is to negotiate a common plan even if individually they show differing levels of satisfaction and perceived process efficiency. Indeed, Ring and Van de Ven [41, p. 112] argue "(developmental processes of cooperative interorganizational relationships) studies must be undertaken using organizational and individual units of analysis" and, thus, our third hypothesis is:

H3: Introducing a formal device based on real options reasoning increases the propensity of the interorganizational groups as a whole to invest in flexible design structures.

We now turn to the analysis of the results from our lab experiments.

C. Simulating Interorganizational Group Decision Making on Capital Design Flexibility

Our lab experiment simulates a front-end planning meeting for a new railway project, and captures the voices of the stakeholders who claim legitimate rights to influence directly the design requirements and, thus, the project scope and budget. As said, the exercise draws from the Salford case and involves six roles: three NR people, a private station operator (profit-seeker user), a university official (not-for-profit user), and a regeneration agency official (statutory body). Table III summarizes the objective functions for each role and the companion information that each participant received a week in advance of the project meeting.[3]

To narrow down the scope of the exercise, each group got a startup pack qualifying seven alternatives including abandoning the scheme, endorsing a rigid design structure or endorsing a wholly safeguarded design (summary in Appendix I). Each group had 3 h to resolve their differences.[4] The experiment was carried on when information publicly available on the scheme was inexistent and, hence, the groups were not biased by the real-world outcomes.

1) Designing a Formal Device: The Design-for-Evolvability Framework: To structure the future-proofing conversations of the experimental groups, we developed a so-called "design-for-evolvability framework" that comprises three stages: 1) analyzing options, 2) designing alternatives, and 3) project strategizing (see Fig. 1).

[3]Students were free to talk informally before the meetings. But they seldom did as they were too busy.

[4]We encouraged the students not to arrange more formal meetings after the 3-h project meeting; they heeded to our advice because they had other priorities and, thus, were not interested in meeting again.

TABLE III
SUMMARY OF THE GROUP PARTICIPANTS' OBJECTIVES AND INFORMATION HANDOUTS

Role	Objectives for each group participant in the front-end planning process	Information provided ahead of the group meeting		
		Design brief	Background	Finance issues
NR Project Manager	· ensure that the scheme goes ahead · meet the industry standards and reduce the capital and operating costs · ensure that the extra capital costs to safeguard the design are shared	Growth forecasts, budget outlays, cost of the design alternatives	NR Route Utilization Strategy (RUS)	Financial contribution to the scheme possible, but not desirable
NR Project Engineer	· meet the industry standards · align the design with the 2020 vision and, thus, safeguard for a third platform	Design standards for the rail sector	NR Route Utilization Strategy (RUS)	NA
NR Commercial Sponsor	· ensure that the scheme goes ahead · protect commercial relationship with the private station operator · develop a landmark station, or at least safeguard for that scenario	Capacity bottlenecks, passengers' movements	NR Route Utilization Strategy (RUS)	NA
University Official	· ensure that the scheme goes ahead · align the station design with the University's campus master plan · build a new platform and a landmark station building	University growth projections, students' needs, capital budget	University campus master plan	Financial contribution to the scheme possible, but not desirable
Regional regeneration Agency Official	· ensure that the scheme goes ahead · build a landmark station building · safeguard for a third platform	Interdependencies with other projects, capital budget	Vision and Regeneration Local Framework	Financial contribution to the scheme possible, but not desirable
Private station operator	· extend the existing platforms · oppose the addition of a third platform · build a landmark station building	Operational needs, planning horizon, business objectives	Operator's response to the NR's RUS	Financial contribution to the scheme ruled out

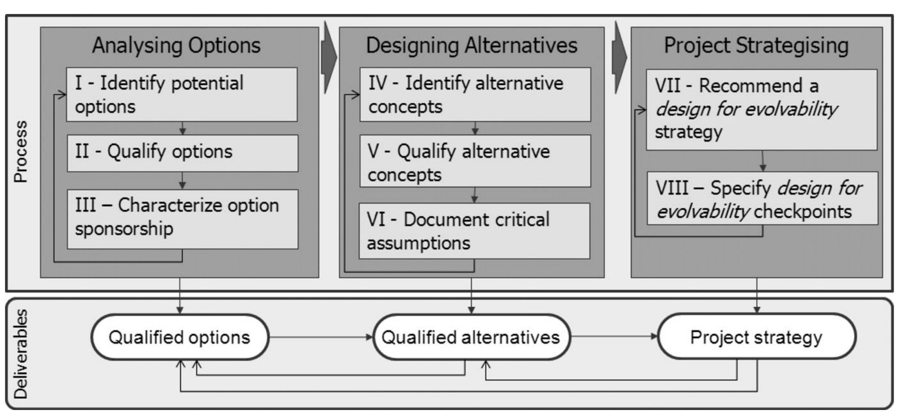

Fig. 1. Schematic representation of the design-for-evolvability framework.

In the first stage, the framework steers the participants to identify desirable options after translating the strategic visions of their parent organizations into operating scenarios. The participants are asked to use real options reasoning to qualify the options including the exercise dates and likelihood of exercising them. They must also discuss how to finance the options. The champion elucidates that the value of an option increases as its expiration date extends because more opportunities to exercise the option exist. This addresses misconceptions that longer exercise timeframes detract value from flexibility [16].

In the second stage, the group has to identify alternative designs that vary in the extent to which the options are designed in. Designs can be understood as the juxtaposition of different layers [11]. Hence, the framework uses the term "alternative" to refer to a higher order design layer; each alternative can then have design options (flexibility) built in or not at a lower level. This stage concludes by documenting the capital costs for each

TABLE IV
DIFFERENCES IN THE PARTICIPANTS' PERCEPTIONS OF EFFICIENCY

	Control		Experimental		
Questionnaire Statements (*)	Mean	StDev	Mean	StDev	*P*-value
All participants contributed to the discussion (input rate)	2.125	1.746	3.154	2.014	0.045 (**)
All participants shared their interests and concerns (communication effort)	2.438	2.250	2.885	1.946	0.258
All participants shared ideas and exhibited creative thinking in overcoming obstacles (mental effort)	2.625	2.247	3.154	2.073	0.226
Efficiency (average 1 through 3)	2.396	2.060	3.064	1.989	0.151

(*) Strongly agree—1; strongly disagree—7.
(**) $p < 0.05$.

alternative, funding pledges, and expected adaptation costs if uncertainties realize later on.

In the third stage, the group has to develop a recommendation and a commensurate funding plan. The experimental groups are instructed to use the options reasoning lexicon to do so and to document the context embedding their decisions. For accountability purposes, they must say how to mitigate the risks of late adaptation if they endorse a rigid design.

To incentivize the students to take the exercise seriously, the groups had to turn in a meeting minute with their recommendation; the students had also to produce a reflective account that counted for the final course mark and participate in a debriefing session in class.

2) Analysis of the Lab Simulation Results: We assessed the impact of introducing a formal device in terms of efficiency, satisfaction, and effectiveness following the ISO's [25] guidelines to assess users' ability to achieve goals using tools. For the qualitative analysis of individuals' perceptions of efficiency, we used standard codes [24], [45] and developed tabular displays. We assessed perceived process efficiency in terms of participants': 1) input rate, i.e., contribution to discussions; 2) communication effort, i.e., sharing of interests and concerns; and 3) mental effort, i.e., sharing of ideas and involvement in creative thinking; we also measured efficiency (using a Likert scale) by aggregating the same three variables (see Table IV).

To assess the participants' satisfaction with the development process, we adapted the Likert-based standard poststudy system usability questionnaire [32] to frame satisfaction in terms of two factors—"system usefulness" and "interface and information quality"—which in turn relate to 17 prespecified items (see Table V).

We assessed the effectiveness of the group as a whole based on the extent the groups converged on a flexible design. If a rigid design is endorsed, the risk of high adaptation costs later on is real due to the possibility that increase in demand and socioeconomic growth will justify the addition of a third platform and a landmark station building. The occurrence of this scenario is plausible over the asset's operating life, but less so during the project. Thus, we expected the experimental groups to recommend designs more flexible than control groups.

We cross checked qualitative data in the documented deliverables against the students' accounts and observations of the meetings. For two experimental groups, we produced verbatim transcripts of the discussions. We observed but did not record any control group because we expected their performance to largely mirror our empirical findings.

The lab results are consistent with the patterns observed in the field studies. There was no conflict over purpose and all groups by and large converged on the need to endorse the scheme; all groups also ditched plans to build a third platform. Only the University was making this claim, but ruled out a substantial financial contribution. Thus, ditching a third platform is rational given that uncertainty is high about whether the investment will payoff and all the claimants operate with tight budgets. The problem then boils down to safeguard or not for a third platform and for a landmark station building.

On this matter, the University and planners insist that the design must be safeguarded but are reluctant to contribute finance since NR owns the station. The NR team has more resources and does not operate under a fixed budget, but needs to be talked into deploying them. The private operator is not interested in contributing to the capital costs of the scheme.

a) Impact of a Formal Device on the Perceived Efficiency of the Future-Proofing Discussions: The analysis of qualitative data suggests that, in agreement with the empirical findings, the efficiency of the control groups was impaired by interorganizational controversies. Left to their own devices, the control groups scrambled to hammer out a deal to finance future-proofing provisions. The participants did not oppose to the idea, but no one was interested in footing the bill and, thus, sharp exchanges ensued. One participant in a control group said:

> "We ended up having four [parties] against two. With regards to the third platform, the other parties were already against it from the start. It wouldn't gonna (sic) matter what we said in order to argue for it. There was no way that we would persuade them."

The lack of a formal device to encourage people to share information further complicated things. As one participant said, "It's not clear to me, whether we should have opened our role details to the others." The findings also reveal the use of radical political posturing during the discussions of the control groups. One operator, for example, suggested abandoning the whole project ("why not [abandon it]? I don't see any point in me investing money").

In contrast, people in the experimental groups heeded to the design-for-evolvability champion and were keen to borrow the options logic lexicon and reasoning to structure the future-proofing talks. The qualitative findings suggest that the experimental groups were more successful in creating space for individuals to come up with ideas to bridge the gaps in interests. For example, the third platform could seem deceptively affordable unless the NR engineer revealed that it required spending

TABLE V
DIFFERENCES IN THE PARTICIPANTS' ASSESSMENTS OF SATISFACTION

	Control		Experimental		
Questionnaire Statements (*)	Mean	StDev	Mean	StDev	P-value
01—Overall, I am satisfied with how easy it was to front-end strategize	2.875	1.137	3.408	1.547	0.016 (**)
02—It was simple to do the project front-end strategizing.	3.400	1.392	3.500	1.449	0.356
03—I could effectively complete the project front-end strategizing.	2.925	1.289	3.144	1.476	0.200
04—I was able to complete the tasks and scenarios quickly.	3.375	1.462	3.615	1.619	0.205
05—I was able to efficiently complete the tasks and scenarios.	3.025	1.250	3.305	1.419	0.133
06—I felt comfortable with the project front-end strategizing process	2.850	1.562	2.787	1.436	0.415
07—It was easy to learn how to project front-end strategize.	3.225	1.577	2.994	1.326	0.212
System Usefulness (Average 1 through 7)	*3.096*	*1.392*	*3.250*	*1.488*	*0.239*
08—The information received as part of the institutional support clearly helped us to fix problems.	2.700	1.363	3.075	1.687	0.093
09—Whenever there were disagreements among participants, the information received as part of the institutional support helped to overcome them easily and quickly.	2.850	1.145	3.454	1.556	0.008 (**)
10—The information received as part of the institutional support was adequate.	2.650	1.477	3.121	1.563	0.053
11—It was easy to leverage the information received as part of the institutional support.	2.975	1.423	3.167	1.486	0.245
12—The information received as part of the institutional support was easy to understand	2.900	1.277	2.494	1.397	0.055
13—The information received as part of the institutional support was effective in helping us complete the tasks and scenarios.	2.875	1.202	2.799	1.474	0.380
14—The institutional support was well structured.	2.575	1.483	2.609	1.473	0.452
15—The institutional support was easy to access.	2.475	1.536	2.351	1.287	0.329
16—The institutional support provided had all the qualities I expect it to have.	2.875	1.539	2.960	1.431	0.385
17—Overall, I am satisfied with the institutional support that was provided.	2.775	1.687	2.557	1.448	0.242
Interface and Information Quality (Average 8 through 17)	*2.765*	*1.414*	*2.859*	*1.514*	*0.373*
Overall Satisfaction (average 1 through 17)	*2.901*	*1.413*	*3.020*	*1.515*	*0.278*

(*) Strongly agree—1; strongly disagree—7.
(**) $p < 0.05$.

Verbatim transcript	Content analysis
DfE champion: What we need to consider here is: first, do we want a 3rd platform? And second, do you want the extension? ... So you need to capture what you think it will be the best for now and what potentially will be the best for the future.	Champion uses options lexicon to frame design problem
Operator: well for us that's a good alternative, but not for now. Why? First, because we will not achieve revenue protection...also it increases our operational costs,...We think it might be a good alternative, but only in the future. **Project manager:** can you further clarify why it's going to increase costs for you? **Operator:** because we need more staff in different parts of the train station as we [will] have multiple access points. […]	Evidence of communication effort and constructive exchanges
Project engineer: just to add on the private operator's comments. The cost of the platform is reasonable, just £3m roughly. But we need some adjacent works such as modifying signalling system and tracks. And that costs much more. **Operator:** how much is that? **Engineer:** it's about £20m. **DfE champion:** that's a significant additional cost. **Operator:** yeah it's basically very expensive... I don't think we can afford that.	Evidence of timely exchange of information
DfE champion: I'm just wondering, as you are the engineer, do you know if there is a way to remove the physical assets and replace that for alternatives that are more advanced technologically. I've heard of mobile phones being used to control tickets.	Evidence of mental effort and creative thinking

Fig. 2. Annotated excerpt of discussion held by an experimental group.

an extra £20 million in prerequisite works. Individuals in the experimental groups systematically shared this information right upfront—the exchange in Fig. 2, captured 20 min after the start of the discussion, illustrates this.

The exception was one experimental group in which the design-for-evolvability champion inadequately performed the role. To the dismay of other participants, this "incompetent" champion hardly intervened and the future-proofing discussions got bogged down; at some point, the NR engineer said: "Money for what? and how much? Why should he (the operator) pay for that landmark building? You (the regeneration agency) should pay!" An incompetent champion thus out rightly short circuited the impact of the formal device.

Unexpectedly, while the qualitative analysis suggests that the device overall improved the efficiency of the future-proofing talks, independent samples T-tests do not show a statistically significant difference and, thus, hypothesis *H1* is rejected (see Table IV; see Appendix II for reliability analysis). Keeping the governance structure flat, a formal device does not therefore substantially improve the individuals' perceived efficiency of the future-proofing talks.

b) Impact of a Formal Device on Participants' Satisfaction With the Future-Proofing Discussions: Our analysis of the participants' satisfaction considered qualitative and quantitative assessments in 127 responses. We conducted independent samples *T*-tests to compare satisfaction. Data analysis overall does not indicate statistically significant differences between the two groups and, thus, hypothesis *H2* is also rejected (see Table Vand Appendix II).

The results are consistent with the analysis of the impact on efficiency. They suggest that the participants in the experimental groups did not push back on formalizing future-proofing talks, but the impact was not statistically significant. One participant in an experimental group described the process as an "enjoyable and useful experience"; another said: "having him [the champion] was important to help channel an outcome and draw out the most from the stakeholders." Still, many participants in the experimental groups found the device laborious and, thus, some lobbied to skip steps and appropriate the device to match their environment, a known practice in processes of technology adoption [40].

Interestingly, the qualitative analysis suggests different reasons as to why participants in both groups produced not fundamentally different scores on their assessments of satisfaction. Hence, people in the control groups denoted frustration with the amount of divergences and the lack of a conflict resolution forum. In contrast, people in the experimental groups found some frustration with having to follow all the extra steps of the formal device. This extra effort is the source of the only two statistically significant differences across statements in which people in the experimental groups were actually less positive than the control ones.

c) Impact of a Formal Device on the Effectiveness of the Future-Proofing Discussions: The analysis of the findings reveals just a marginal increase in the propensity of the experimental groups as a whole to future proof. Eight of the 11 experimental groups (73%) recommended alternative D, while the remaining three leaned toward F, conditional on finding available funds. Of the nine control groups, seven (77%) recommended alternative D, while two produced unclear recommendations. These results, which are consistent with *H3* being rejected, suggest that introducing a formal device to facilitate future-proofing discussions has no discernible impact on final group outcomes.

These results differ from the outcome in the real world, where a rigid scheme was endorsed. In marked contrast, in the lab experiments, the groups as a whole showed more good will to future proof and, thus, chose to either interpret the budgetary constraints as soft (but not so soft to commit on a new platform) or to dodge the financial problem. This suggests that the propensity of the groups to future proof was exaggerated in the lab studies.

Importantly, our analysis suggests that even if categorically the recommendations from both groups did not show significant differences, the *quality* of the content of the recommendations produced by the experimental collectives was superior. The differences pivoted around the ideas for financing the future-proofing provisions. The experimental groups produced more credible recommendations because they were supported by evidence of a documented debate on the costs and benefits and financial issues; and the real options lexicon improved the clarity of the outputs. One participant in an experimental group wrote:

> "Once we agreed upon the design, it came down to a matter of sourcing funds . . . . We all understood the urgency of the situation . . . this resulted in some creative negotiations that involved the promise of future commitments in the form of a percentage of future revenues."

In contrast, the proposals of the control groups were more fragile, kick-the-can down-the-road type, dodging the difficult funding issues; as one participant in a control group said "We had no trouble to agree on the alternative D, but we didn't discuss how to finance it."

V. Discussion

A. Flexibility in Capital Designs

Building flexibility in a capital design is a judgemental task that involves balancing needs to keep the project budget under control with needs to ensure that the asset copes with foreseeable uncertainty in requirements and, thus, balancing affordability with adaptability.

This tradeoff plays out at different nested layers of hierarchical design decision making. Some tradeoffs address high-order decisions, e.g., to develop a third railway platform to accommodate growth in demand versus to just safeguarding for this scenario (versus doing nothing). Other tradeoffs pertain to lower order design decisions. If a decision is made to safeguard for a future new platform, it must be decided whether to just build the foundations or also safeguard for other building systems. Hence, designing flexibility works like a set of nested Russian dolls. Once a flexible design structure is endorsed at a higher level, a question pops out on how far to go. As lower level design flexibilities are endorsed, the capital costs go up commensurately and, thus, a cascade of context-sensitive judgment calls ensues.

Critically, upfront decisions on design flexibility (or lack of) are hard to reverse. Once funding is secured for a concept, the upstream systems can quickly move into implementation (detail design and physical execution) even if the implementation for the downstream systems happens years later. Reworking upstream systems after starting to implement them can be prohibitively expensive. Hence, due to the interdependencies between upstream and downstream systems, upstream decisions constrain irreversibly the downstream solutions.

The irreversibility of the front-end decisions would be less of an issue if decisions to invest in a flexible design structure had marginal impact onto capital costs and, thus, erring on the side of caution was not problematic. But in the case of infrastructure, designs show high levels of integrality and, thus, built-in flexibility requires substantial capital investment [16]. In the Salford case, for example, adding a third platform would push up capital costs several fold, and just safeguarding for this scenario would increase the project budget in at least 25%. Hence, decisions to design in flexibility involve tradeoffs between finding extra funds for a flexible design with uncertain payoffs versus let future generations sort out the costs of adapting a rigid design if and when the design requirements do change.

Considering the operational longevity of infrastructure and the downside risk of premature obsolescence, future proofing would be less problematic if capital resources were plenty. It would also be less complicated if the design options were likely to get exercised in the project time. However, the timescales for the payoffs are long which complicates design choices. The problem gets further amplified due to the collective action issues discussed next.

1) Interorganizational Development of Flexible Designs: A Collective Action Problem: The judgemental choice between a rigid and a flexible infrastructure design happens in a context of collection action. The decision is not up to a unitary organization, but to a group of autonomous heterogeneous actors all of which (claim to) have legitimate rights to directly influence the design requirements and, thus, to influence the project scope and budget.

The asset owner (NR in our cases) has rights exofficio to directly influence the design requirements. They share those with bodies who have planning powers, such as the Councils, the custodians of the land. The extent to which user groups have rights to directly influence the design varies. But influential user groups hold tacit knowledge of needs-in-use and other resources, and the promoters need to include them in development to access those resources.

During future-proofing discussions, some parties may advocate investments in design flexibility, but rule out financing them because they operate under tight budgets, do not own the asset, or cannot see the immediate return. Others may be fine to live with rigid designs because they see low chances of foreseeable uncertainties occurring or believe in coping with them through operational and technological changes when it comes to it. Disagreements notwithstanding, the claimants need to converge on one high-level design to forge ahead with the scheme and, thus, face a collective action problem [19], [20].

Conceptualizing the development of flexible infrastructure as a collective action problem challenges traditional boundary conditions for applying real options theory. In macroinvestment situations, for example buying an airport with an option to add a new runway, the option cost is marginal relative to the option value, and the decision to invest or not is internal to the payer's organization [10], [50]. In contrast, design options in infrastructure are the outcomes of multiparty negotiations. People may not disagree that the investments will benefit future generations, but the uncertainty in the payoffs will spur some people to prioritize capital investments with shorter term gains.

We had hypothesized that a formal device based upon real options reasoning would facilitate future-proofing discussions. Our lab experiments do not refute this claim, but suggest the impacts are moderate. Under a flat governance structure, the formal device helped the interorganizational groups to build common ground and cooperate, but did not produce a statistically significant difference in the participants' satisfaction and perceptions of process efficiency; the formal device also did not significantly change the shared outcomes categorically, even if it produced qualitative improvements to the content of the outcomes.

It remains unclear whether the lab results would be different were the formal device based on real options pricing methods. Quantitative models have proved effective to inform investments on design flexibility when the decision falls on to a unitary organization [6], [7], [10]. Pricing models allow for more objective evaluations by quantifying the uncertain payoffs against the certain upfront cost of flexibility, and by allowing sensitivity analysis to account for divergences in numeric assumptions and logic. Hence, they arguably produce more convincing recommendations. But in a group where the autonomous parties are yet to enter into a legally binding agreement, it remains unclear who should foot the bill for producing the analytical models in first place.[5]

Irrespectively of using or not a formal device, convergence would be less complicated if some parties were excluded from the future-proofing talks. The larger the group, the more difficult it gets for its members to converge [42]. But the parties involved in future-proofing talks either cannot be excluded because they have decision-making rights exofficio or are users and, thus, excluding them would deprive others from their knowledge of needs in use and potential financing. Hence, the excludability from the planning process in a democratic society is low.

At the same time, the parties will diverge over the value of design flexibility and, thus, rivalry between their preferences for the final design is high—and the more so the scarcer the capital resources are and the less time is available for the autonomous parties to seek consensus. When high rivalry (in design choices) juxtaposes with low excludability (in design claimants), Gil and Baldwin [19] argue that the *design-in-the-making* qualifies as an Ostrom's [42] common-pool resource and, thus, can be subject to commons governance.

[5]In the UK, the use and training on Building Information Modeling soared after the government promulgated their use mandatory in public infrastructure schemes; in theory, a similar approach could be adopted to encourage use of real options pricing in cost-benefit evaluations of future-proofing provisions.

TABLE VI
SUMMARY OF THE DESIGN ALTERNATIVES FOR THE LAB EXPERIMENT

Design alternative	Design flexibility built-in	Estimated capital cost of the alternative	Options built-in and cost of exercising	Salient advantages	Salient disadvantages
A) Abandon the project	N/A	No extra cost, resulting in £200 000 in sunk costs	–	No extra investment is committed	Huge risks to reputation if accident happens; closure of station remains imminent
B) Extend the existing platform (for six-train cars)	Rigid Design	Unclear, but less than a £2 million	–	Attenuates, but does not resolve overcrowding problem	Closure of the station remains imminent; some disruption to operations
C) Add a third platform	Very flexible design *Conservatively safeguarded for growth in demand*	∼£20.8 million	–	Radical increase in capacity right from day one after project completion	Highly disruptive to operations; capital cost to modernize track (£20 million) not covered by government grant
D) Declutter, move ticket office to south; extend existing platform; safeguard for extra platform in the future	Moderately flexible design *Minimal design safeguards built-in*	∼£7.5 million	Safeguard expansion and development of a landmark station building; ∼£18 million to exercise option	Eliminate overcrowding in the short-term, create capacity to cope with projected increase in demand up to 2025	Disruptive to railway operations; capital cost of design safeguards (∼£2 million) not covered by government grant
E) Declutter, move ticket office to west or east; extend the existing platform	Rigid design *Enhanced relatively to (B) to further eliminate congestion in the short-term*	∼£4.9 million	–	Attenuates, but does not resolve the overcrowding problem	Disruptive to operations; overcrowding problems in the medium-term; precludes economic development of third platform and landmark station
F) Declutter; move ticket office to south; extend existing platform; add a third platform	Very flexible design *Conservatively safeguarded for growth in demand, and enhanced relative to (C)*	∼£30.3 million	Safeguard development of a landmark station; slack to cope with capacity increase	Radical increase in capacity from day one after project completion	Highly disruptive to railway operations; capital cost to modernize track (£20 million) not covered by government grant

2) Changing the Governance Structure of the Interorganizational Front-End Planning: When the *design-in-the-making* qualifies as a common-pool resource, Gil and Baldwin [19] argue that a governance structure that meets Ostrom's principles to design a robust commons encourages social norms of collaboration to flourish. Under robust commons governance, the claimants to the final design show more willingness to compromise, reciprocate, and agree to invest in flexible designs at the expense of other capital investments.

The governance structure of the groups, both observed and as simulated, shows major fragilities from a commons theory perspective. First, low-cost mechanisms were absent to resolve the conflicts around future proofing because governance was wholly flat as opposed to polycentric and, thus, only one layer of decision making and power was available. As a result, the local groups could not defer conflict resolution to higher level groups that would attend to the local interests. Hence, unless the local groups resolved their differences, impasse would ensue—an undesirable scenario given the lack of conflict over the superordinate goal.

Second, there were no entities accountable to all participants and tasked to monitor the quality of the planning decisions from a life-cycle cost perspective.[6] Insofar the final design did not violate existing NR design standards, no sanctions were in place to dissuade the groups from ditching future-proofing provisions and from underplaying the life-cycle risks. Hence, people had limited accountability for the final decisions to future proof or not.

As a result of these fragilities, even if the roles of the participants were clear and some had discretionary powers to finance design flexibility, the future-proofing discussions were rife in disagreements, delayed arrangements, a high risk of impasse, and the outcomes determined by leveraging power imbalances. In some cases, the balance of power was with the local authority, as when NR backed down (with marginal costs) after Reading threatened to veto the planning application. In other cases, the balance of power was with NR, as when NR dug in and insisted it was only prepared to endorse its preferred choices for the design, whether rigid (the case of Salford) or flexible (the case of Warrington), creating a credible threat of impasse. The lab results are interesting because the experiments exacerbated the propensity to relax budget constraints, which attenuated the influence of bargaining power in the outcomes.

Gil and Baldwin [19] argue that, if the right to veto decisions over the final design is shared among the claimants under a robust and polycentric (multiple centers of power) governance structure, this "design commons" approach enables the local groups to find solutions that work reasonably well for all. Indeed, the threat to veto the planning application made NR cave in to the demands of the Reading Council. Had the Council not been

[6]Interestingly, NR operated under a public mandate to account for life-cycle costs, but respondents suggested that NR practices and organization structure were impediments to implement the mandate.

able to make a credible threat, perhaps the outcome would have been different. In contrast, in the other cases, the Councils had no power to veto and, thus, NR played the upper hand.

However, it remains indeterminate whether sharing the power of veto, even accounting for robust governance, would not substantially increase the risk of impasse. Gil and Baldwin's [19] argument is grounded in observations of a polycentric governance structure where local groups are small and relatively homogeneous—all claimants are local stakeholders and, thus, they relate strongly to the final goal, and no profit-seekers share the power of veto. In marked contrast, the groups that we studied and simulated were way more heterogeneous. They not only brought together claimants operating under a public logic with profit seekers, but also brought together claimants with local interests with others less sympathetic to local needs. Hence, sharing the power of veto could disproportionately increase the risk of impasse.

Other recent interorganizational group studies of relatively homogeneous actors operating under no centralized hierarchy show consensus can be achieved by allowing plenty of time for knowledge contestation and justification [54]. Suspending deadlines avoids inefficient Pareto outcomes because it gives parties more opportunities to interact and create knowledge and, thus, resolve the controversies. Again, capital projects like railway schemes are different. They involve many heterogeneous parties that operate under urgency due to political calendars, annualized budgets, or because the problems must be solved quickly. Hence, the parties have limited time for exchanging knowledge, produce convincing evidence, and seek consensus and, thus, have no alternative but to negotiate which creates a risk of winner-takes-it-all outcomes that alienate some parties and hinder further cooperation.

VI. Conclusion

In this study, we trace the flat governance of interorganizational groups formed to plan a new infrastructure to the difficulties in investing in flexible design structures. We show that a collective action problem is central to the development of a flexible capital design.

The higher order goal of designing a long-lived asset to evolve is not controversial, and the problem is seldom technically complex to solve. But because flexible capital designs require significant investments, tradeoffs ensue between endorsing rigid designs at risk of high adaptation costs versus expensive flexible designs at risk the options may not be exercised.

In addition, insights from a lab experiment suggest that, under a flat governance structure, a formal device (based on real options reasoning) to facilitate an interorganizational group to converge on the value of design flexibility is unlikely to fundamentally change the outcomes. When the local groups cannot defer the resolution of their differences to higher level bodies, and budget and schedule constraints are hard, the extent flexibility gets designed in is contingent on the preferences of those with more bargaining power.

There are important limits to the generalizability of our insights. Our research is grounded in the cash-strapped Britain's railway sector. The UK planning system is very strict for historical reasons, and designed to protect a strong regime of property rights. These conditions may not be observed in other institutional environments surrounding capital projects where higher level authorities of one party may be granted powers to unilaterally resolve local divergences, effectively centralizing decision-making power at the higher levels.

Contextual differences notwithstanding, asking a group of autonomous parties to self-design a flexible asset under conditions of uncertainty, flat governance, and resource scarcity is a tall order. The challenge gets amplified when capital projects are one-off. This is the case of infrastructure, where the participants seldom benefit from the experience and shared understanding accumulated from long-standing relationships, or the "shadow of the future" that sustains robust collaboration [15]. Exploring more polycentric forms of governance seems to us a promising avenue to create a capital project environment amenable for these "strange bedfellows" to better exploit the value of design flexibility.

Appendix I

See Table VI.

Appendix II
Factor Analysis of Satisfaction Data

Because of the categorical nature of the dataset, there was no problem of outliers to contend with. Similarly, there were no missing values. The factor analysis was conducted using principal axis factoring as the extraction method, and Oblimin with Kaiser normalization as a rotation method. The two factors are: factor 1 (interface and information quality) and factor 2 (system usefulness). Relevant results follow. The KMO statistic = 0.885 indicates acceptable sampling adequacy for the analysis. Similarly a significant Bartlett's test result (p value = 0.000) provides strong justification for this particular analytical approach.

As can be seen, items clearly load on to each factor as anticipated and satisfy the conditions of construct validity in terms of discriminant validity (loadings of at least 0.4 and no cross loadings). Thus, the validity of our data and findings is confirmed. Note that the two factors obtained share a significant correlation coefficient of 0.538 ($p < 0.01$).

KMO and Bartlett's Test

Kaiser–Meyer–Olkin Measure of Sampling Adequacy.		0.885
	Approx. Chi-Square	1630.737
Bartlett's Test of Sphericity	df	136
	Sig.	0.000

TOTAL VARIANCE EXPLAINED

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
Factor	Total	% of Variance	Cumulative%	Total	% of Variance	Cumulative%	Total
1	8.549	50.288	50.288	8.160	48.001	48.001	7.312
2	2.377	13.983	64.271	2.010	11.823	59.824	6.069
3	0.935	5.498	69.769				
4	0.841	4.950	74.719				
5	0.713	4.193	78.912				
6	0.594	3.495	82.407				
7	0.532	3.129	85.535				
8	0.424	2.497	88.032				
9	0.333	1.961	89.993				
10	0.328	1.928	91.921				
11	0.278	1.634	93.555				
12	0.257	1.515	95.070				
13	0.229	1.345	96.415				
14	0.189	1.112	97.527				
15	0.186	1.094	98.621				
16	0.155	0.910	99.531				
17	0.080	0.469	100.000				

PATTERN MATRIX[A]

	Factor	
Item	1	2
1		0.793
2		0.854
3		0.864
4		0.830
5		0.761
6		0.470
7		0.525
8	0.652	
9	0.835	
10	0.683	
11	0.551	
12	0.877	
13	0.765	
14	0.703	
15	0.765	
16	0.832	
17	0.806	

FACTOR CORRELATION MATRIX

Factor	1	2
1	1.000	0.538
2	0.538	1.000

The factors were then tested for reliability (internal consistency) using Cronbach's α. According to Hinton *et al*. [23], the latter results indicate that both constructs demonstrate excellent reliability. A parallel reliability analysis was conducted on the efficiency data with results as follows, and once again the items were found to have excellent internal consistency.

RELIABILITY STATISTICS

Factor	Cronbach's Alpha	*N* of Items
Factor 1 ("Interface and information quality")	0.935	10
Factor 2 ("System usefulness")	0.900	7
Efficiency	0.967	3

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