THE UNIVERSITY OF MANCHESTER

Strategic Capabilities for Megaproject Architects: Sequencing Network Growth and Bottleneck Removal

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Working Paper

November, 2015

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This study discusses strategic capabilities necessary to improve the performance of the promoters of new developments of large infrastructure so-called megaprojects. To get to the end goal, promoters must assemble vast networks of resource-rich, autonomous actors and share with them direct control over high-level design decisions for indivisible components. Hence promoters are 'system-architects', and they need architectural knowledge both of the stakeholder landscape and technical design to carry on their task structure. Promoters that act strategically, we argue, deliberately manipulate the sequence of arrival of the actors and keep a selected few at bay. An ideal sequence aligns the growth of the network with the hierarchy of design choices and creates cohesive groups to strike consensuses on local solutions. We discuss pitfalls ahead of attempts to orderly eliminate development bottlenecks and thus stabilise performance expectations, a prerequisite to sustain public legitimacy for the scheme.

INTRODUCTION

Megaprojects, the organizational networks formed to develop large infrastructure such as airports, railways and power plants, the backbone of modern society, are an important form of public-private partnership. Infrastructure gaps, traditionally the preserve of developing economies, are now a major issue for developed economies too. The case of United States is telling. Cities like Boston are notorious for their crumbling public transport systems; and the multi-billion dollar damages caused by the Hurricanes Sandy and Katrina, and late deadly bridge collapses, have spotlighted the country's chronic underinvestment in infrastructure.[1] Population growth, rising sea water levels, and migration flows are phenomena all expected to amplify infrastructure needs throughout the century at a time many governments are cash-strapped. Improving megaproject performance is thus paramount since global spending—in the order of four trillion dollars yearly—is way short of meeting future worldwide needs.

[1] For a detailed view of the global infrastructure gap see, for example, the Global Competitiveness Reports that are yearly produced by the World Economic Forum.

Regrettably, bridging infrastructure gaps has become all more challenging after dramatic cost and schedule overruns have fueled suspicions that megaprojects are rooted in dishonest and/or incompetent behavior. Mistrust and bad vibes have led to a loss of legitimacy for megaprojects in the eyes of the public and other third parties, complicating the job of the politicians and businesses promoting new schemes. Infamous cases of megaproject overruns are universal ranging from Boston's Big Dig, a project that rerouted the city's central artery into a tunnel, and new Olympic parks in Sydney and Athens to Berlin's new airport, World Cup football stadiums in Brazil, and the extension of London's Jubilee underground line.

This study aims to turn the page on this debate by unpacking the strategic capabilities that megaproject promoters need to acquire to do a better job. Central to our argument is the claim that promoters are 'system architects', and thus we need to understand the structure of their tasks, and the strategic capabilities they need to carry on the tasks effectively and efficiently.

Drawing from literature on the development of complex products and systems, we argue that megaprojects are a complicated form of organizing production activities since the multiparty organizational structure behind a new development is sharply misaligned from the monolithic structure of key functional components in any large infrastructure. This structural misalignment forces autonomous actors including governments, public agencies, businesses, and nonprofits to seek consensus on the design of the assets that they will share in use later on. Since the end goal is to produce long-lived, capital-intensive assets, the stakes are high and thus new infrastructure developments are ridden with interorganizational conflict.

Yet, megaproject promoters that are adept, we argue, rather than passively accepting that 'wicked' planning problems (Churchman, 1967; Rittel & Webber, 1973) are endemic to these enterprises act strategically to attenuate structural misalignment. In this study we propose two intertwined strategic capabilities rooted in the system architect's knowledge of technical design and stakeholder landscape. Technical design knowledge involves understanding the

system components, how they interface, and the rules governing the interfaces (Baldwin & Clark, 2000; Henderson & Clark, 1990). This knowledge is necessary to identify the hierarchy of design choices, assess interdependencies between choices, and the sequence of design decisions. Knowledge of the stakeholder landscape in turn is critical to design the structure of participation in the megaproject organizational network—this is, to identify which actors should join (and when) the working groups formed to develop the infrastructure components.

A megaproject promoter that has architectural knowledge can strategically plan a sequence to eliminate bottlenecks in development which dampens the risk of late slippages in the performance targets (Baldwin, 2014). Specifically, the promoter can do two things. First, it can align the hierarchy of design choices with the growth of the megaproject network. Commitments on high-level decisions should be made after the claimants to system-wide choices are on board so as to create a high-level solution space that can cope with a variety of potential local pressures. And second, lower-level design choices should not be locked in without involving key local players that have a stake in the outcome. If decision-making groups are delineated to legitimate claimants, the promoter can expect less uncooperative behaviour and free riders who refuse to compromise and make claims wholly disproportional to their stakes.

An alignment of the sequence the development deals with the growth of a network of legitimate claimants can mitigate risks of late arrivals of steamrollers who attempt to overturn commitments made in their absence. This, in turn, reduces the need for the promoter to, first, build massive budget and schedule contingencies so as to have organizational slack for coping with late disruptive claims[2]; and second, to engage in tough bargaining processes and

[2] This practice was taken to the extreme in the UK after Treasury issued guidance on the need to substantially adjust cost and schedule forecasts with optimism bias factors, a practice that is unsustainable

tricky political activity for fending off political attacks on upfront development decisions. In summary, an adept promoter acts strategically to influence how the environment ‘shapes’ the network (Miller & Lessard, 2000). In so doing, chances reduce of development failures in terms of impasse, endless iterations or unaffordable deals whilst keeping the decision-making process democratic (O'Mahony & Ferraro, 2007).

We ground our argument on a four-year long empirical study of four megaprojects in the UK (Lundrigan, Puranam, & Gil, 2015). Three schemes were mostly publicly financed: London Olympics, Crossrail (a high-capacity London railway), and HS2 (a high-speed railway connecting London and the Northern regions). The fourth, a new terminal (T2) at Heathrow airport, was financed by BAA, the airports’ private owner. Our sample of 121 interviewees included: i) top management and technical staff from BAA, UK government, London government, and public agencies; ii) design consultants and contractors; and iii) user groups such as Star Alliance (the occupier of T2), local governments, and owners of interdependent infrastructure such as Network Rail (the owner of the UK railway infrastructure) and Transport for London.

In addition to interviews we examined hundreds of archival documents such as technical and strategic project reports, parliamentary reports, design documents, and minutes of board meetings. We also examined commercially sensitive documents, e.g., cost reports, design change logs, and project dashboards, shared after we formally committed not to disclose the original documents under any circumstances. Finally, we invited 12 practitioners to give talks to our students and stay for lunch, documented numerous informal conversations, and developed detailed factual accounts for each case that we circulated for comments.

The remainder of this article is structured as follows. First we discuss the structural misalignment problem central to large infrastructure development and how megaproject promoters can develop strategic capabilities. We then examine the promoter’s task structure

and the capabilities necessary to carry on those tasks well. Finally we discuss how promoters who act strategically align the growth of the megaproject network with the hierarchy of design choices whilst keeping mindful of the pitfalls with any ideal sequencing strategy.

MEGAPROJECTS: A PROBLEM OF STRUCTURAL MISALIGNMENT

Megaproject networks are not self-organizing systems. Rather, they combine elements of open and flat structures characteristic of distributed communities of production such as open source with the closed and stratified hierarchical structures found in OEM-supplier networks and managed business ecosystems (Gulati, Puranam, & Tushman, 2012). Leading this organizational network is the megaproject promoter—typically a coalition of actors unified by the grand idea. For example, the development of the Olympic park was led by the London and UK governments together with the British Olympic Association, whereas the T2 development was led by BAA, the airport owner, Star, an alliance of airlines, and the regulator. As the systems architect, the promoter is responsible for guiding the growth of the megaproject organizational network concurrently with the development of the technical design for the infrastructure. Promoters do so by influencing the boundary conditions and the distribution of decision-making rights.

The megaproject promoter does not have, however, absolute control over the high-level decision-making process. Rather, at the core of the network where strategic decision are made, the promoter shares direct control over the decision-making process with other autonomous actors which are unified by the superordinate goal and control non-substitutable resources. The boundaries of the core are porous as would-be designers can force their membership through virtue of the resources they hold. Within the core, decision-making is therefore consensus-oriented as no single body holds enough resources to force a decision.

In contrast, the periphery of the megaproject network is closed and populated by design and build suppliers that hold substitutable resources that can be acquired on the market. The suppliers join the megaproject through a process of selection and their relationship is governed by formal contracts that simulate an authoritative hierarchy (Stinchcombe & Heimer, 1985). Suppliers contribute labor and technical expertise, but have no direct control over strategic development decisions.

A central point in the literature on the development of complex products and systems is that the misalignment between organizational and product design structures is a source of managerial complexity (Colfer & Baldwin, 2010; Henderson & Clark, 1990; Sosa, Eppinger, & Rowles, 2004). This lack of mirroring occurs when the technical system is hard to decompose, but the design tasks are complex and thus require technical expertise that is fragmented across different units of a company or firms. To improve work coordination across boundaries, modular designs should be developed by modular organizations whereas integral designs are better developed by tight-knit teams lodged within a single organization.

A problem of structural misalignment is also central to new infrastructure development. Infrastructures are systems of indivisible components. For example, an airport includes runways, concourses, and a control tower; a railway includes stations, tracks, and control systems. Each non-decomposable component is shared in use by many autonomous actors who directly influence development because they control resources that are not up for sale and are critical for the scheme to forge ahead, e.g., land, finance, planning consent, and political support. Hence infrastructure developments create at the core, perforce, large arenas of consensus-oriented collective action wherein ‘wicked’ planning problems surface which are hard to resolve to the satisfaction of all the potential members of the production network.

Complicating matters is the ‘one-off’ nature of megaprojects. The development participants rarely have prior experience of working together, nor do they operate under the

shadow of potential future developments. The fact they will share the asset in use may thus not be enough to develop robust relational contracts, agreements that require a long time to forge as they presuppose clarity of goals and credibility of both parties (Gibbons & Henderson, 2012). Rather, in the planning phase the megaproject promoter must rely, at best, upon fragile 'Memorandums of Understanding' that cannot be legally enforced and can be reneged upon with surprising ease.

Conflicts notwithstanding, the megaproject promoter must lead searches for mutually consensual design solutions whilst keeping to global performance targets in terms of schedule and cost to sustain legitimacy for the enterprise in the eyes of third parties. Striking a consensus on a design is difficult when the claimants are drawn from different ideological, institutional, and epistemological frames. Exacerbating difficulties is the potential absence of key claimants at the outset of development. This creates a real risk of late arrivals of new claimants who disagree with prior decisions prompting another round of discussions that put pressure on performance targets committed to upfront. Slippages of targets fuel accusations the promoter was dishonest or lost control over the enterprise. Hence the promoter faces a delicate balance in that to keep the scheme on target requires authoritative decisions which create a risk of alienating resource-rich actors who can defect or lobby to overturn decisions.

STRATEGIC CAPABILITES FOR THE MEGAPROJECT ARCHITECT

Strategic capabilities are bundles of valuable routines which guide decision-making of managers at a micro level and of organizations at a macro level (Dosi, Nelson, & Winter, 2000). These valuable routines find their roots in the distributed knowledge held by individuals. Within an organization, the dissemination and combination of individuals' knowledge allow for the development of increasingly complex decision-making routines. Thus strategic capabilities are built from a hierarchy of knowledge beginning at the task-

specific and individual level, and progressively integrated towards bundles of routines which inform higher-order decision-making for the organization as a whole. Literature on capabilities is motivated by fundamental questions about how organizations operating in competitive markets can survive in the long term (Eisenhardt & Martin, 2000; Teece & Pisano, 1994).

In marked contrast, megaproject promoters do not compete in market settings where the ability to adapt and overtake rivals is a necessary part of strategizing[3], nor do they need to concern themselves with organizational survival in perpetuity—the megaproject network disbands once the infrastructure is up and running. Still megaproject promoters need to be strategic to get to the end goal. Megaprojects are capital-intensive enterprises that compete for scarce resources, and thus their sustainability during the planning period (which lasts years) cannot be taken for granted, and indeed many major schemes collapse in planning.

Promoters have, however, limited opportunity to develop strategic capabilities through repeated experiences, and thus have to rely on 'primitive accumulation'—a process which allows capabilities to emerge without full understanding of final operating conditions (Dosi et al., 2000; Lave & Wenger, 1991). Primitive accumulation requires employing experienced staff drawn from a community of practice who are familiar with the environment and technologies at hand, and information-sharing processes to facilitate learning from prior experiences; primitive accumulation also relies on the experience and know-how of professionals who perform established job roles. Thus, in the planning stage, the capabilities of the megaproject promoter can be considered a patchwork of heterogeneous knowledge drawn from subject-matter experts. To speed up capability development, the promoter recruits seasoned managers for non-executive and executive roles who bring a wealth of

[3] However this does not imply that megaprojects exist in a static environment; changing economic and political conditions can always pose a threat to a megaproject's survival.

contacts and 'lessons learned' from prior undertakings[4]. This recruitment process contributes to an institutionalized process of isomorphism (DiMaggio & Powell, 1983), and indeed the megaprojects which we studied exhibit similar organizational structures and development processes. Crucially to the point of this study, the presence of common practices across the sample suggests opportunity to develop promoters with strategic capabilities to guide the development of the megaproject network and the technical design.

In product development, strategic capabilities encompass two interrelated subsets—one pertaining to the social or contractual system, and another to the technical system (Baldwin, 2014; Baldwin & Clark, 2000). In megaproject settings, the social and contractual capabilities guide the growth of the network that develops and builds the artefact. To first achieve a mutually consensual design solution, the promoter needs to set the organizational boundaries, stratify decision-making rights, identify resource-rich actors, and integrate them into the network. Once the planning problem is out of the way the promoter needs to procure an array of suppliers to carry on the design and build tasks, and to write the contracts that govern the buyer-supplier relationships.

Figures 1 and 2 illustrate the growth of the megaproject organizational networks for Heathrow T2 and London 2012 throughout the development life-cycle, and the concomitant evolution of the cost forecast in final prices. In the first stage, ideation, an idea emerges that unifies a leading coalition of autonomous actors—this entity becomes the promoter and has direct control over the global performance expectations, e.g., total cost, completion date, and the design requirements or scope. This stage is followed by planning during which the promoter engages in analytical deliberations, bargaining processes, and political activity with

[4] For example, the CEO of the Olympic Delivery Authority is now chairman of HS2 Ltd.; the CEO of Crossrail Ltd was construction director of the Heathrow 's T5 project; the CEO of HS2 Ltd used to be capital projects director at Network Rail; the T2 capital director was the director of the UK largest nuclear complex, etc.

a vast array of actors to develop a viable plan to achieve the gran idea. In the final stage, implementation, the suppliers are selected to carry on the engineering and construction work.

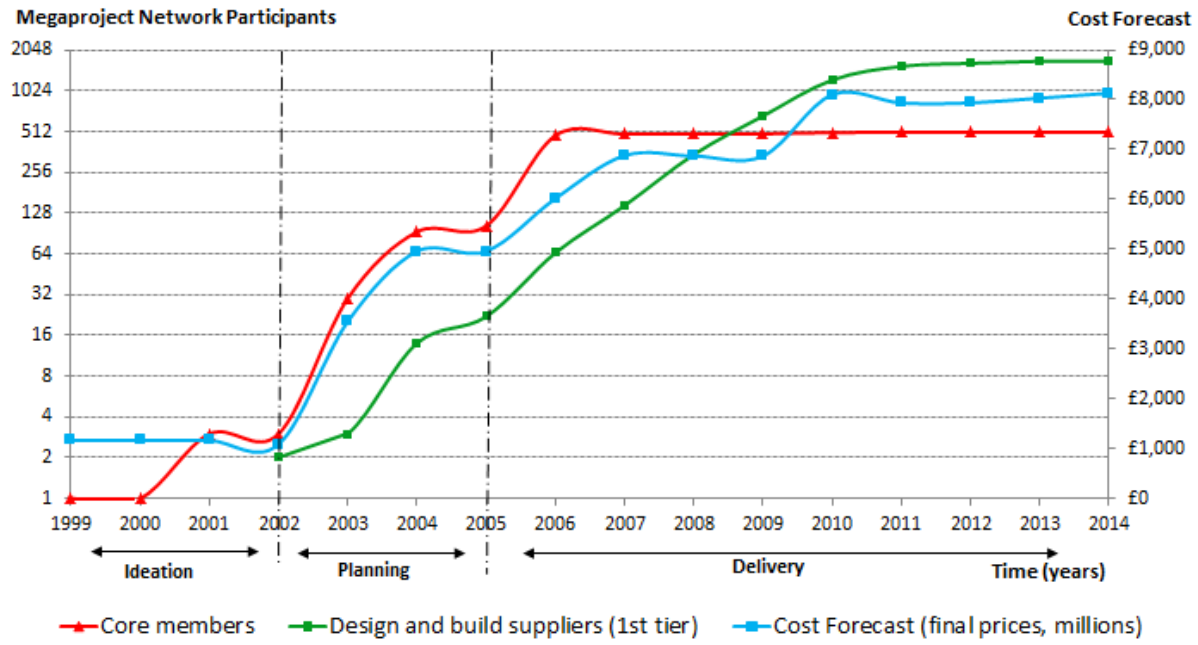

Figure 1 Relationship Between growth of the 2012 Olympic Park meta-organization and infrastructure cost

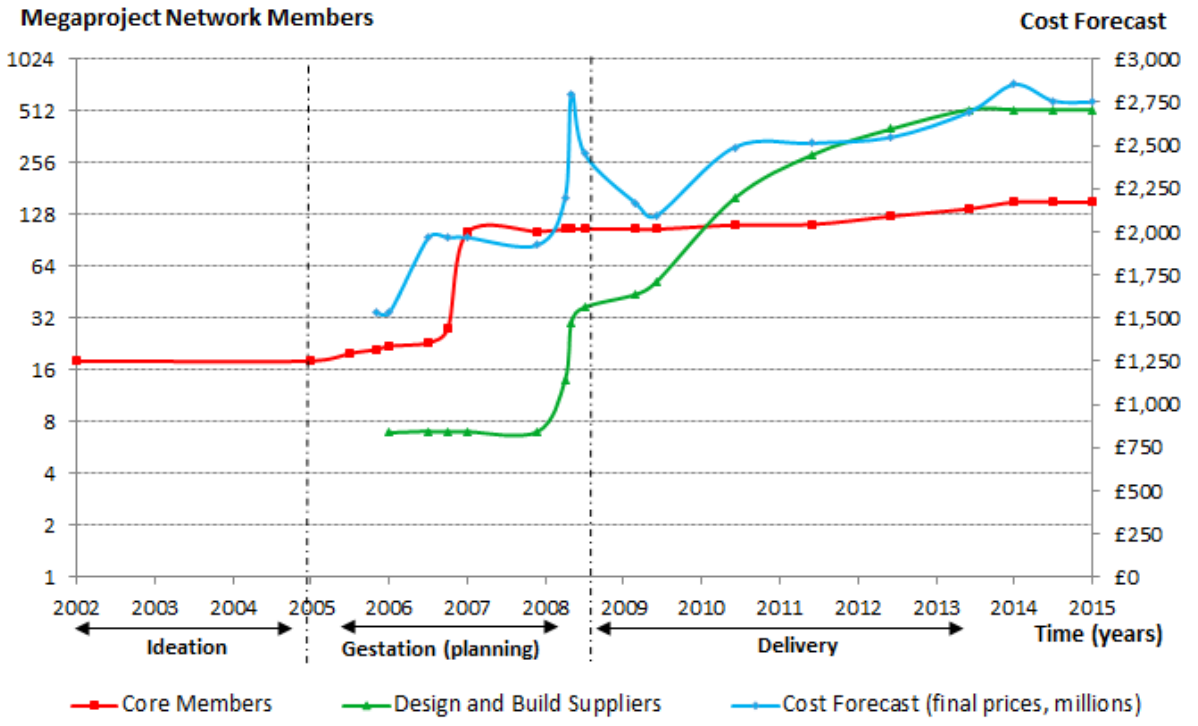

Figure 2 Relationship Between growth of the Heathrow T2 meta-organization and infrastructure cost

Technical capabilities guide the development of the infrastructure components and the rules governing how the components interface. For example, developing an Olympic park requires deciding which sport venues to include, their capacities, which ones are temporary vs. permanent, and producing a master plan exacting the location of the venues, the Olympic village, and the media centre. Likewise, developing an airport terminal involves deciding the number and shape of the concourses, the layout of the tunnels and bridges for people and baggage to move around, and the interfaces between the concourse gates and the airfield.

In summary, megaproject promoters need architectural knowledge to understand the architectures of the organizational network and of the technical design for the infrastructure. Each of these architectures consists of a design structure and a task structure (Baldwin, 2014; Baldwin & Clark, 2000). The design structure specifies components and their relationships, whilst the task structure consists of the activities necessary to instantiate the design structures. We turn now to discuss the task structure of the promoter and then the strategic capabilities needed to carry on the tasks well.

THE TASK STRUCTURE OF THE MEGAPROJECT PROMOTER

At the onset of a new infrastructure development the megaproject promoter faces two main tasks: i) grow the organizational network to attract much needed resources; and ii) develop a technical design for the new infrastructure—the basic set of instructions expected to show how to allocate resources commensurately with the resources that have been acquired. In lieu of ownership stakes or employer-employee relations, to exert influence, the promoter has to rely on resource dependencies, technical expertise, and reputation (Gulati et al., 2012; Maier, Emery, & Hilliard, 2001).

Hence it is the task of the megaproject promoter to corral resource-rich actors in the core to conform to a shared development strategy. But if a promoter engaged all potential

claimants at the same time this could create an unmanageable sprawl of claimants risking making even the most basic decisions excruciatingly difficult. Thus, the promoter seeks first to produce a concept that satisfices the powerful actors and brings momentum and legitimacy. This concept frames the goal and is used to convince other actors of the scheme's viability and worthwhileness. Still, the risk is real of powerful actors arriving late and attempting to force the promoter to renege on earlier decisions in favor of their own preferences. Reneging on prior decisions is hazardous for the promoter who risks defection of former supporters.

The extreme operational longevity of infrastructure amplifies the difficulties in striking a consensus in development. Given the high stakes, some claimants will ask a high price for their cooperation and rule out losing an argument without a fight. Hence, to carry on the dual tasks of developing a technical design and the corresponding organizational network, the promoter must engage in analytical deliberations side by side with bargaining processes and political activity—a pattern typical of collaborations which aim not at producing innovative outcomes but at 'getting things done' and sustaining legitimacy in the eyes of third parties (Lawrence, Hardy, & Phillips, 2002).

For example, the coalition leading the Olympic Park had to work with over 100 claimants to the final designs including local governments, landowners, sport associations, interest groups, political parties, and the International Olympic Committee; it subsequently selected over 1,500 first-tier suppliers to carry on the design and build tasks. Likewise, the coalition leading the T2 scheme worked with over 150 claimants to the design including non-Star airlines, local governments, and retailers, and over 500 first and second-tier suppliers.

As the megaproject promoter persuades other autonomous actors to contribute their resources, the network's core becomes gradually misaligned from the indivisible technical designs. Complicating the promoter's task is the lack of absolute control over who has a legitimate right to influence the technical design. Many actors are non-substitutable, i.e., their

resources cannot be easily replaced. For example, if the promoter of the Olympic Park failed to garner the support of the International Olympic Committee then the scheme would fail. The promoter is also limited in resources and cognition (Simon, 1972) and thus not privy enough to the preferences of other actors to have a complete understanding necessary to develop ex-ante a convincing design that would satisfy their claims. For example, the Crossrail scheme began with a design concept limited to central London; by the time the claims of other actors were incorporated in the design the scheme had evolved into a Greater London commuters' train.

The structural misalignment that grows as an infrastructure development forges ahead is common to pluralistic enterprises—the involvement of more parties attracts extra resources that potentially bring a benefit for all to enjoy but leads to problems of appropriation due to conflicting interests (Garud, Gray, & Tuertscher, 2014; Ostrom, 1990). In the case of infrastructure, the misalignment occurs irrespectively if the system as a whole is decomposable or not (Gil, 2015). In the case of the modular Olympic park, for example, just to resolve the design of the stadium, the promoter had to engage with fifty claimants with differing preferences for what the local goal should be in legacy varying between an athletics venue, a football stadium, and a dual-purpose venue. Misalignment problems have also beset the more integral HS2 scheme after local governments asked central government to supply more money for developing world-class stations and long tunnels to minimize property blight. In this case, controversies have been exacerbated due to technical interdependences across the stations and the need to preserve equitability across cities.

In summary, the megaproject promoter treads a precarious path. On the one hand development choices in terms of technical issues and cost and schedule forecasts must be kept flexible enough to accommodate differing preferences. On the other hand, those choices

must be robust enough to attain, and maintain, firm commitments from the first actors to join the network. We turn now to discuss the capabilities needed to perform this job effectively.

THE CAPABILITY TO SHAPE THE MEGAPROJECT NETWORK

As said a primary task of any promoter is to design the structure of the megaproject organizational network. The boundaries of the core are porous and the promoter has limited influence to keep powerful actors at bay. But not all actors are powerful and resource-rich. For those with limited resources and no legal rights to enter the core, it is up to the promoter to decide what to do. We distil the capabilities necessary for the promoter to exercise good judgment in two sets: *identify* potential members and *select* members where appropriate.

Identification of Potential Members of the Megaproject Network

Megaproject promoters rarely if ever are powerful enough to operate alone, and thus must seek out potential new members which are willing to volunteer their resources in aid of the scheme. But these actors are not altruistic. Resource-rich actors will only support a scheme in return for the right to directly influence development, and they may choose to withdraw support should they become dissatisfied with the promoter's bargain. This necessity of acquiring critical resources may be described in terms of technical and strategic bottlenecks(Baldwin, 2014).

Technical bottlenecks are technological constraints that hinder the performance of a system. One example can be drawn from the Heathrow's T2 case. In early designs BAA proposed that Star used an old baggage system located in another terminal to process their customers' luggage. This would potentially slow down Star's operations and thus constrain system performance. With BAA unwilling to invest upfront in an entirely new baggage system and Star unwilling to accept the initial design, a deadlock ensued. The bottleneck was removed after a technological solution surfaced—BAA would safeguard for Star's ambition

by building in T2 a large basement for a new baggage system to be installed in a second phase. A second example pertains to the development of the HS2 stations. Here the cities turned down the government's proposed designs because of the lack of integration with the old stations. The principle that doing so improves HS2 performance is consensual. But technologically no easy solutions exist yet to carry out the necessary works without severely disrupting day-to-day operations. Faced with this bottleneck, the designs remain unresolved.

Strategic bottlenecks arise when an external party controls an irreplaceable resource for a system to function. Hence, in megaprojects, actors that hold vital resources inherently control strategic bottlenecks and have power to directly influence the technical infrastructure design especially in regimes with strong property rights. If a promoter fails to negotiate with a party holding a strategic bottleneck then a deadlock ensues until either a solution surfaces that bypasses the need for that particular resource, or the resource-rich actor changes their stance.

In the case of Crossrail, for example, the initial London-centric concept was shelved twice after it met strong political opposition in Parliament. Only after the promoter changed the system-level goal to a commuters' train, Crossrail succeeded to inch forward. A second example is the support of the Mayor of London to the HS2 scheme which is conditional on getting finance to build another railway so-called Crossrail 2. The Mayor's claim that HS2 will choke London's underground transport system is contestable, and the promoter has demurred to change the HS2 high-level design. Doing so could create a dangerous precedent likely to weaken the promoters' bargaining power in negotiations with other actors. But ignoring the Mayor's claim creates a real risk of major disruption later on. Since the issue is hard to bypass by appealing to a higher-order authority, the parties continue to search for a mutually consensual solution that will allow eliminating this strategic bottleneck.

In summary, the competency with which the promoter identifies the bottlenecks, as well as who controls the resources necessary to eliminate the bottlenecks, impacts the capability to

carry on the design tasks. Delays in resolving the issues also increase the risk of late slippages in the performance expectations which affects the scheme's public legitimacy. We discuss next how promoters that are strategic influence which actors enter the network's core.

Selection of Potential Members of the Megaproject Network

Once a megaproject promoter identifies the actors who control strategic bottlenecks, the question that follows is whether the promoter has power to *select* them to join the network. If the environment does not offer any realistic alternative to an incumbent resource-rich actor, the issue is not one of changing one actor for another. And indeed in many instances the decision to join the network's core rests solely with the resource-rich actors themselves—a process that is akin to the self-selection mechanism witnessed in open networks.

For example, in the UK, property-right holders who will be 'materially affected' by a new infrastructure have de jure rights to ask for design changes by lodging a petition with Parliament, the only institution that can give powers to the promoter to compulsory buy land. If the promoter fails to cut a deal with a petitioner, it must then put its faith in the Parliamentary process to uphold prior decisions. To reduce uncertainty and gain time, an adept promoter discerns actors who categorically oppose to the scheme from others who show appetite to cooperate. The HS2 and Crossrail promoters understand this well and both have mobilised substantial resources to hammer out private deals with potential petitioners. And even when the promoters fail to persuade key actors not to petition they vigorously engage in private talks outside Parliament to persuade them to withdraw the petitions.[5]

In other cases, actors may not have de jure rights to enter the megaproject network's core but are powerful enough to conquer de facto rights. One example is the involvement of the football clubs in the development of the Olympic stadium. Two clubs claimed rights to

[5] Despite the promoters' efforts, the number of petitions remains large – 365 lodged against Crossrail (although 261 were later withdrawn) and more than 2,000 against HS2 (first phase). The Parliamentary process is a major source of uncertainty and delays. But calls to eliminate the process have fell flat as society at large sees it as needed to uphold the principles of democratic decision-making and a strong regime of property rights

directly influence the final design whilst ruling out contributing finance. The promoter deemed this attitude inappropriate and hit back by rejecting the legitimacy of the football clubs' claims[6]. Still, the clubs remained powerful[7] actors who were able to drum up support for their idea and managed to force the promoters' hand after a protracted fight.

In other situations the promoter can indeed decide over whether to include or exclude actors from the network's core. Local communities, for example, only need to be consulted by law and thus the decision to let them directly participate in decision-making is in the promoter's hands. The same is true for key user groups. Bringing users on board encourages them to volunteer tacit knowledge of needs-in-use, and thus facilitates the acquisition of this sticky resource. But this knowledge is not a strategic bottleneck per se as the promoter can choose to press ahead with its own design choices regardless of opposition from user groups.

The megaproject promoter therefore faces a trade-off when mulling over giving dubious claimants access to the strategic decision-making process and veto power on the final design choices. Letting more claimants into the network potentially brings in useful resources but also increases rivalry in preferences. And once the promoter invites one actor to join in it cannot exclude that actor unless it goes back on his word. This juxtaposition of rivalry in design choices between non-excludable parties transforms high-level design choices into a shared resource (Gil & Baldwin, 2013). And creates a real risk of development failure if some actors refuse to compromise and reciprocate, a risk that is amplified the larger the group sharing power.

A megaproject promoter who is knowledgeable about the stakeholder landscape can identify a priori the actors that definitely need to enter in the network's core, those that can be kept at bay with limited risk of disruption, and those whose status hinges on a judgement call.

[6] We use legitimacy in terms of what is legitimate in the face of socially-accepted norms (see Suchman, 1995)

[7] We use power here in a Weberian sense (Weber, 1947), and thus capable to force someone to so something they otherwise would not do.

This knowledge is also needed to anticipate the extent actors are likely to cooperate or not. In contrast a less capable promoter struggles to discern potential co-operators from free riders because it cannot comprehend how the resources each actor controls shape future behaviours. Poor judgements lead to emerging controversies that put pressure on the performance targets.

It also falls to the megaproject promoter to select the suppliers that will perform the engineering and construction works through market mechanisms. These suppliers rarely have rights to directly influence strategic decisions. But uncertainty in the design requirements complicates the relationship between the promoter and suppliers. This uncertainty juxtaposed with the high specificity of one-off transactions increases the risk that suppliers act opportunistically to push up costs (Williamson, 1975). A discussion on how promoters can approach the market efficiently under these challenging circumstances is, however, outside the scope of our study.

THE CAPABILITY TO DEVELOP A TECHNICAL DESIGN

Concurrent with the organizational growth of the megaproject network, the promoter must oversee the development of a technical design. Taken as a whole infrastructure systems are usually at least partially decomposable into components that can be developed relatively independently. Thus the megaproject promoter can stratify stakeholders into local working groups delineated to the actors with a legitimate stake in the component of interest; each group is then tasked to find out a ‘satisficing’ (Simon, 1956) design through a consensus-orientated search.

To guide the design discussions, the megaproject promoter needs to draw upon prior architectural knowledge of similar technical systems and adapt it to local requirements. Promoters that lack sufficient technical knowledge supplement it by employing one or more expert suppliers. Early technical designs are simplistic potentially consisting of the key core

functional components of the future operating system. As the promoter attracts increasing supporters for the scheme, they too will have a role in identifying potential components, subcomponents, and in elaborating the rules governing the interface between the components.

The development process gets tricky because the system-level design decisions are governed by a coalition. The membership of the coalition may become fixed after a few years of high-level talks, but controversies still run rampant between the members. One example is the development of Heathrow T2. The organizational structure of the coalition was consolidated after three years of high-level talks between BAA, Star, and the regulator. But goal congruence was low as Star pushed for a grand vision for Heathrow T2 to match the rival's facilities whilst BAA pushed for a more modest piecemeal approach. Reconciling their differing preferences took in total six years of deliberations and tough negotiations during which it turned out impossible to accurately forecast the final costs and opening date.

When moving from discussions on system-level decisions to the design of particular components the number of claimants spirals. Hence it is at component level that the misalignment between organization and design structures becomes more acute. In the London Aquatics centre, for example, 29 claimants were involved in the initial design discussions including local governments, user and interest groups, and owners of interdependent assets; the number had grown to over 50 claimants when the time arrived for the suppliers to join in, and we compiled similar figures for the Crossrail and HS2 stations and T2 concourses (Lundrigan et al., 2015).

The extent the component development processes are interdependent varies according to whether the infrastructure as a whole is modular in a strict technological sense, e.g., Olympic park, or more integral, e.g., railways. Irrespectively, the difficulties of seeking mutually consensual local designs are invariably amplified by global budget and schedule constraints. Throwing more time and money into a design sub-problem can resolve a local problem. But

local slippages put pressure on global targets and thus create a tricky precedence and equity issues. And for some infrastructure, a delay in developing one component has a knock-on effect on other components. Thus decisions to let local targets slip are seldom taken in haste.

Adding flexibility to the design structure also attenuates conflict because it leaves options open and thus lowers future adaptation costs (Gil, 2007; Gil, Biesek, & Freeman, 2015; Gil & Tether, 2011). But to 'future proof' large integral designs against an array of foreseeable claims invariably demands investment in costly safeguards, e.g., deeper foundations, redundant equipment, and may sacrifice operational performance. This opens the proponent of flexible designs up to criticism and is not uncommon that cost concerns win out when the budget is tight or people run out of time to continue the debate.

The case of the terminal gates at Heathrow T2 is telling—the design participants failed to reach a consensus on whether the gates should be open or closed. BAA, the airport owner, preferred open gates to bring down capital costs and facilitate the circulation of passengers up to the time they needed to board the aircraft. In contrast, some airlines insisted to operate with closed gates which they deemed more efficient. A potential way out was to develop a flexible design but BAA fiercely opposed to the idea—the company was investing in a new generation of boarding technology, and a solution of compromise would hike capital costs in a few million pounds. The fight between the two parties only got resolved after the issue escalated to an arbitrator which recommended indeed investing in a flexible design solution.

In summary infrastructure design is the outcome of consensus-oriented searches for local solutions which vary in degree of technical interdependence but invariably unfold constrained by global cost and schedule targets. We turn now to discuss how the megaproject promoter can combine technical and organizational design capabilities to improve performance.

Aligning Network Growth with Design Co-Production

The two capabilities described herein are inherently interrelated as the choices of social structure influence the choices of technical structure and vice versa. At the outset of a new development the megaproject promoter crafts an infrastructure design concept that establishes the boundaries of the system-level goal. The future asset will encroach on the property rights and interests of many environmental actors and thus development bottlenecks ensue. As the promoter, driven by necessity, seeks to eliminate bottlenecks with the support of these actors pressure grows to change the design. New deals impact an ever widening circle of environmental actors, and make slippages in cost and schedule forecasts almost inevitable.

Slippages in performance targets fuel a variety of readings that range from accusations of dishonesty and incompetency, to sunk cost fallacies, escalation of commitment to a failing goal, and claims that megaproject outcomes are shaped by the environment (Flyvbjerg, Bruzelius, & Rothengatter, 2003; Miller & Lessard, 2000; Morris, 1994; Ross & Staw, 1993). We argue, however, that the root cause of the problem lies not in agency or environmental issues but on the 'catch-22' situation that megaproject promoters face at the onset of a new scheme—the technical architecture cannot be accurately established without the totality of the social architecture, and yet the social architecture cannot be specified without some semblance of a complete design and corresponding performance targets.

To conform to upfront performance targets and thus sustain legitimacy in the eyes of third parties, promoters could try to force their design preferences. But since the promoter lacks absolute authority, unilateral actions are likely to backfire. The promoter could also engage in endless iteration until a mutually consensual solution surfaces, but in practice promoters operate under rigid timescales dictated by election and regulatory cycles. This leaves the promoter with fewer options to get things done. One option that has received much attention pivots around combining deliberative processes with mutual-gains bargaining and political activity. These are commons mechanisms to get things done in interorganizational

collaborations that lack a shared understanding of the problem that brings people together, and seems unrealistic to do without them. But the point here is that they do not need to rule new infrastructure development. And indeed, our argument suggests that promoters can act strategically to pre-empt conflict and attenuate pressure on performance targets by manipulating the growth of the network. We turn now to discuss how promoters can leverage the architectural knowledge of the organization and product design structures to this purpose.

Strategically sequencing the Growth of the Megaproject Network

Megaproject promoters have limited strategic choice in selecting powerful actors within the environment but can influence when they join the network; promoters can also select less powerful actors. Promoters who have architectural knowledge of the organizational and design structures, and know how to harness it, can thus identify which actors should join the network's core first and be party to high-level decision-making processes. By manipulating the growth of the network, the promoter restricts the flow of new members whilst intentionally not leaving behind any resource-rich actor. By acting strategically, the promoter can gradually seek consensus on designs that encroach on the flexibility hitherto enjoyed by all claimants. As a respected and enduring consensus takes shape, a deep technical design structure (Gersick, 1991) can also emerge that locks the development participants into particular final design choices and is robust to sustain late attacks from claimants with limited legitimacy.

To plan an optimal sequence for the entry of members in the megaproject network's core, the promoter needs to derive their priority from the importance of the resources under their control. Bundles of resources which are most critical to eliminate bottlenecks can be assessed by considering the number and centrality of the components that require those resources. For example, the monopolistic owner of Heathrow airport operates in a regulated environment—no plan for a major infrastructure development can therefore progress without the airport

operator securing first from central government political backing, a non-substitutable resource. Hence the early targets for a megaproject promoter to purse are those actors who control resources with impact on the system-level elements. The actors who hold global resources are by definition very few, and thus they should be part of the leading coalition.

Once the structure of the leading coalition is firmed up, and system-level design decisions are agreed, the development must proceed to decisions over individual components[8]. This requires the promoter to identify the bottlenecks stymieing the development of particular components, and bring into the network those actors, and only those, who control resources that are non-substitutable and necessary to remove those bottlenecks. For example, to forge ahead with the HS2 scheme, central government had to set up for each city on the route a local working group. Whilst the central government plans to finance the scheme in its entirety, it is virtually impossible for government alone to decide where to locate the railway stations and how each station interfaces with the surrounding built environment. Hence government has no alternative but to engage in a genuine effort with the city leaders to search for mutually consensual design solutions which will eventually involve supplementary local finance. Figure 3 schematically represents the archetype of a sequencing strategy that aligns the growth of the megaproject network with the concomitant co-production of the design.

[8] In practice the development process is more iterative, but a linear presentation is chosen for the sake of clarity in presenting the argument

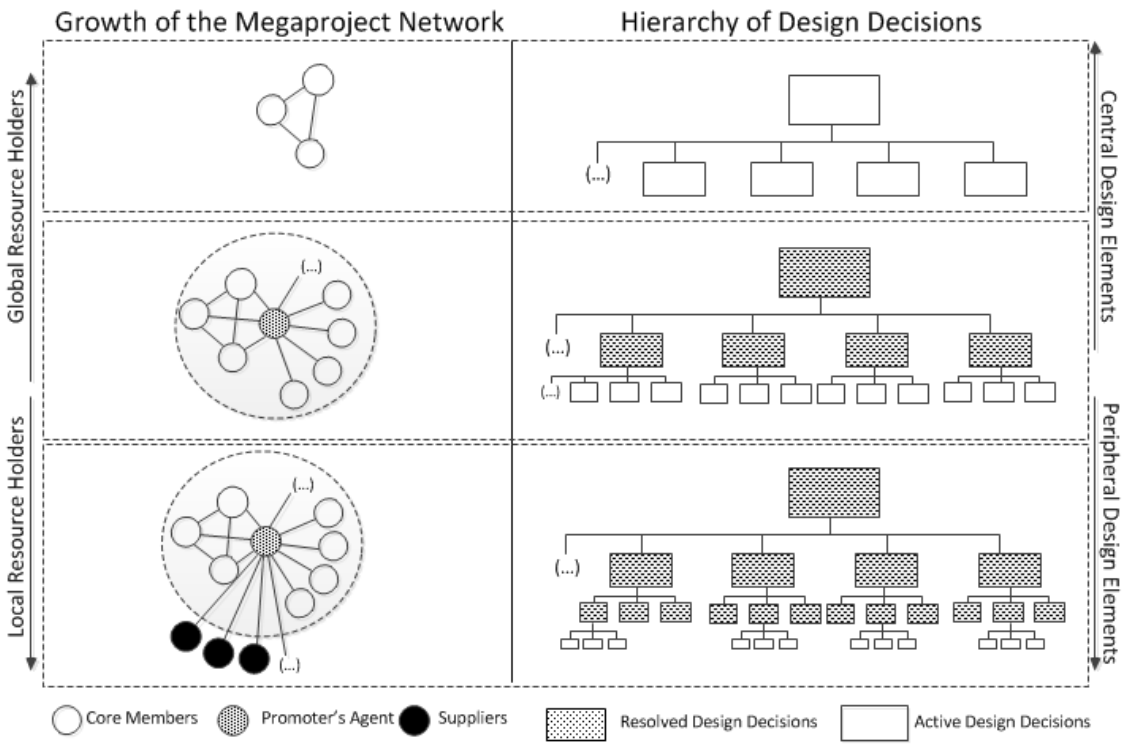

Figure 3 – Strategic alignment of megaproject network growth and design co-production

A similar rationale of aligning component design choices with the arrival of the corresponding resource-rich actors can be extended to key user groups. Legal frameworks typically oblige the megaproject promoter to consult users, but rarely give users ex officio rights to directly influence the development process. Still, users own tacit knowledge of needs-in-use. This knowledge is a non-substitutable resource that is hard to acquire unless users see an incentive to volunteer it, and one incentive that works is to share with users the right to directly influence development of the components they care with (Gil & Baldwin, 2013). Failure to appreciate this can lead to costly late change. The case of the Aquatics centre is telling. Faced with spiralling costs the promoter unilaterally chose to ditch over thirty design items that had resulted from conversations with the user groups including moveable pool floors, greater numbers of temporary seats, and a sophisticated roof system.

The decision provoked an outcry, and in the subsequent year most elements found their way back into the final design.

By manipulating the growth of the megaproject network, the promoter pairs together early claimants to the final design with flexible, less formal contracts and later entrants with more rigid, formal contracts. Early entrants need flexibility to engage in wide ranging discussions, whilst late comers can encounter a more constrained solution space. This agrees with the use of non-enforceable Memorandums of Understanding (MoUs) to govern the development at the early stages when the key parties lack predisposition to commit to a well-defined obligation. And with evidence that suggests that as development progresses, parties warm up to the idea of folding MoUs into formal contracts. In this way the promoter can attenuate rifts due to differing interests between actors that joined the network first and latecomers, as well as reduce chances of the former going back on their word. This in turn contributes to increase the stability of the performance targets, and thus sustain public legitimacy for the scheme. We turn now to discuss the pitfalls ahead of plans to implement any ideal sequencing strategy.

PITFALLS TO SEQUENCE THE MEGAPROJECT NETWORK GROWTH

We have derived our argument from interrogating data on the consensus-oriented planning of four megaprojects. However, the analysis reveals instances where our argument holds well as well as flagrant violations of the ideal sequencing strategy postulated here. Violations invariably led to controversies that beset the sample cases, and contributed directly to the slippages in the global targets that affected all the schemes without exception (illustrated in Figure 1 for the cases of the Olympic park and T2 cases). These violations were nonetheless not sufficient to founder the planning efforts—all developments but HS2 succeeded in planning after a history of prior failed attempts; and whilst HS2 is still in planning, the principle of it has been approved by Parliament, and has thus jumped this major hurdle.

This suggests the alignment of the hierarchy of design choices with the arrival of the claimants to the megaproject network's core is not a necessary condition to keep an infrastructure development afloat. Rather it is an archetype of a strategy that is context sensitive and subject to variation in implementation. If we accept suboptimal strategies can still lead promoters to the end goal, it matters to discuss which factors drive promoters to deviate from our ideal strategy—after all, in so doing, the promoter incurs the risk of conflict imploding later on and jeopardizing the public legitimacy of the scheme. In the discussion that follows, we group the pitfalls facing a plan to implement a sequencing strategy in four categories. These pitfalls either offer good reasons to deliberately deviate from an ideal strategy or create a situation where implementing that strategy is simply not in the cards.

The perils of building large collective action arenas too fast

First, the megaproject promoter must be wary of the inherent risks in consensus-oriented collective action. Pluralistic organizations are advantageous to attract voluntary contributions of resources that when pooled together enable to achieve objectives that a single organization alone cannot achieve. But getting things done in any collective action arena is a struggle (Dietz, Ostrom, & Stern, 2003). This struggle exacerbates in large infrastructure developments where potential claimants are drawn from across ideological, institutional, and epistemic boundaries, and thus the risk of conflict is high due to semantic, syntactic, and pragmatic differences; large groups with fewer prospects to work together again further complicates mutual cooperation (Ostrom, 2005). Hence while an ideal strategy suggests promoters do not want to exclude key resource-rich actors from high-level development decisions on the components they care, the arrival of these claimants to the network's core can create unintended complications that promoters also need to be mindful.

The HS2 development is telling of this pitfall. The promoter of HS2, the central government, made a deliberate choice to exclude local governments from formal high-level

conversations about which cities the new railway should be connecting and the best route for connecting the cities. Lacking strategic local input, but eager to make a public announcement of the final route choice and corresponding cost and schedule targets, the HS2 promoter relied on the owner of the national railway network to make educated guesses about the outcomes of future local discussions. Once the promoter established the working groups with the city leaders to agree the designs of the stations, pressure mounted to relax the cost targets and indeed the targets have slipped (although the source of finance remains unresolved).

For the promoter, however, the risk of making educated guesses was far outweighed for what it calculated were greater risks had it involved upfront the local players. Indeed the promoter was wary of failing to even agree an inter-city layout and outright losing public legitimacy for the scheme if it opened up the discussion prematurely. Doing so could fuel all sorts of rumours difficult to quash around property blight, and substantially increase the risk of the scheme becoming a political football and collapsing. Hence, promoters should not ignore the perils of rushing to build a large collective action arena. Undefined boundaries amplify difficulties to get to consensus and can turn collective action arenas easily into chaos.

The perils of delaying the arrival of powerful claimants

Whilst good reasons can exist to delay the arrival of resource-rich actors into the network's core, a second pitfall facing the megaproject promoter is the potential risk of losing legitimacy for the scheme if it delays the arrival of powerful actors. Collective action arenas are complicated enough to govern when there is proportionality between costs and benefits (Ostrom, 1990). So promoters that act strategically do not further complicate matters by deliberately opening up the arena to resource-poor actors that are unwilling to cooperate and strike a consensus.

. Our findings show, however, that it can be really difficult to implement this principle. Some actors, when realising that they are being kept at bay from early development talks,

may run low on patience and start attacking politically the scheme. These actors may rule out contributing resources in exchange for the right to directly influence the design. But if the stakes are high, they will not be ready to lose without a fight. A fight can potentially make it harder for the promoter to both attract new commitments of resources from other actors and maintain commitments from extant members. Even if going for a fight is the right thing to do, it can thus be difficult for a promoter to hold on to their nerve as opposed to cave in to fear.

One good example is the case of the football clubs that gained de facto rights to directly influence the development of the Olympic stadium right after the UK won the bid. As aforementioned the clubs' participation was not altogether desirable since they shied away from making any substantial financial contribution. But the promoter was wary of excluding the clubs concerned that drawing the battle lines that way could spur a political fight. The risk would then be high that the clubs would lobby aggressively for design changes, seeding discord within the coalition, and causing havoc. The decision to include the football clubs irked, however, the athletics community that had backed the Olympic bid on the basis that the Olympic stadium in legacy would become an athletics venue. Impasse was temporarily avoided at the eleventh hour by adopting a rigid design for the games that served neither group optimally; consensus on using retractable seating to build a dual-purpose venue (an idea ruled out in the first two years of planning) was finally reached one year after the games. By the time a deal surfaced the costs had almost doubled the initial forecast.

An immovable deadline arguably can make it harder for the promoter to stick to an ideal sequencing strategy, and dig its heels in the face of a real external threat of disruption to the planning process. We discuss next how in other cases violations of an ideal strategy are motivated by internal factors in the face of time-bounded opportunities.

The risk of passing up time-bound opportunities

A third pitfall facing megaproject promoters that can encourage them to violate an ideal sequencing strategy is the risk that not doing so squanders time-bound opportunities to acquire vital resources to move forward with an idea that has been going around for years. Whilst megaprojects create in the short-term substantial economic activity and jobs, their long-term socio-economic value is often subjected to vivid, inconclusive debates.. Decisions to forge ahead therefore rarely occur insulated from budgetary and electoral cycles. Eagerness to seize time-bound opportunities can force the promoter to accelerate the rate at which the network's core becomes misaligned from high-level development decisions. As key claimants to those decisions finally join the party, slippages in performance targets ensue.

This was the case of London2012. Only if the Olympics contest was won could the promoter acquire the wherewithal to, first, regenerate a large swath of derelict land in East London; and more importantly, to increase the capacity of London's congested transport networks which some pundits argued risked sparking riots in a near future. However, the rules of the game set by the International Olympic Committee (IOC) accounted only for two years to put together a bid. This was patently insufficient to work out a detailed plan and commensurate cost forecast, but the promoter deemed the opportunity too good to be missed.

The pledges in the bid documents around the legacy for London and inclusiveness swayed the judges and the promoter acquired the vital resource to forge ahead. After the victory, the promoter coined the slogan 2-4-1: two years to plan, four to build, and one to test. But overnight it found itself facing claims on the final design choices from over 120 claimants and engaged in negotiations to expropriate 350 landowners. When the time to start construction arrived, the promoter had yet to resolve many emerging controversies; by then the cost forecast had already slipped £1bn relative to the original forecast. To avoid further slippages, the promoter then built a massive £3bn contingency on top of a £6bn cost forecast.

The three pitfalls so far discussed have led to violations of an ideal sequencing strategy that were ultimately the choice of the promoter. This is, the environment did not force the promoter to act the way it did, but rather the promoter responded to the environment. But this is not always the case, and we next discuss pitfalls rooted in unforeseeable events.

The risk of unforeseeable events upending strategic plans

A final pitfall faced by megaproject promoters in attempting to sequence the arrival of claimants is the extent that they can accurately evaluate the quality of the resources controlled by potential actors. It is not unusual for the development life-cycle of a new large infrastructure from ideation to handover to operations to last more than one or two decades. As time goes by, the status of some design participants evolves and sometimes changes dramatically. Actors that were strategically selected to join the core may lose the capacity to contribute the resources pledged upfront, and new actors then have to be found late in the process to overcome new bottlenecks that arise unexpectedly.

One example is the major iteration that occurred less than two years away from the opening of Heathrow T2 after Star lost its key domestic airline. The leading coalition had deemed inconceivable that this event could occur in the short-term. And when it did, it caused havoc in the occupancy strategy for T2, leaving the promoter with the risk of opening a terminal too big for the new needs. The promoter had then to find new occupiers with new preferences for the final design, and embark on a £100m iteration to redesign the whole internal layout. To make up for lost time, BAA unilaterally attempted the redesign much to the ire of Star. This turn of events was ironic since the size of T2 had been a contentious issue after BAA rejected Star's original preference for an even larger campus.

A second example is the loss of the private developer expected to finance the Olympic village. The developer was appointed in 2007 and went ahead and selected various architectural practices to design a massive village in line with its own commercial goals and

the criteria negotiated between the megaproject promoter and the International Olympic Committee. But by mid-2008, hit by the financial crisis, the developers' capacity to finance foundered. It then took two years for the promoter to identify an alternative financial backer putting pressure on an already tight schedule. In the midst of a late iteration, a deal was struck to develop a much smaller village and transform part of it into social housing after the games.

In summary, the four pitfalls highlight that good reasons can exist not to implement an ideal sequencing strategy even if some of the reasons are not universally accepted, and indeed are morally condemned by some observers. In other cases, even the best laid plans of megaproject promoters can become unstuck for reasons beyond their control. These exceptions may be common but their impact reinforces our argument—a strategic effort to align the sequence of entry of members into the network with the hierarchy of design choices gives the promoter a modicum of control in what can otherwise turn into a chaotic system.

CONCLUSION

In this study we begin by elaborating on the task structure of the megaproject promoter—the coalition at the helm of a new infrastructure development. We show how the development of the organizational network and the technical design are two parts of the same coin. As the design must meet the preferences of key resource-rich actors, the promoter cannot accurately specify the requirements until the network acquires its key core members. And yet, paradoxically, these actors are unlikely to support the scheme without first seeing details of the would-be design. It is the job of the promoter, a systems architect, to balance developing a design which is detailed enough to convince key actors to commit individually-controlled resources whilst keeping that design flexible enough to accommodate emergent preferences.

To perform their tasks well megaproject promoters need to foster two strategic capabilities. First, they need to be capable to identify which actors in the environment control

which resources; they also need to discern which potential claimants can only enter into the network if the promoter selects them versus those who are resourceful enough to elbow their way in. And second, the promoter needs to be capable to understand the architecture of the technical system, and thus the resources necessary to eliminate emerging bottlenecks.

The sequencing strategy that we conceptualize calls for promoters to synchronize the arrival of new actors to the network's core with the hierarchy of design choices. Resource-rich actors that claim legitimate rights to influence system-level decisions should enter the network's core. As high-level decisions get crystallised, it is then the turn to involve local actors with legitimate stakes to search for mutually consensual local design solutions.

Aligning network growth with design decisions does not eliminate all controversies. Hence sequencing is not a substitute for building organizational slack in the form of budget and schedule contingencies. But by attenuating problems of misalignment, more opportunity exists to reduce slack and mitigate its downside risks notably of self-fulfilling prophecies. Crucially, megaproject promoters that are strategic are not hostages of how the environment shapes network growth. They recognize that any ideal sequencing strategy can only be implemented imperfectly given the pitfalls ahead. But they still seek to leverage architectural knowledge to shape the network growth and the sequence of controversies that ensue.

Put differently, a megaproject promoter that is strategic shows enough political astuteness to attempt to avoid falling prey to a messy arena of collective action wherein restricted information flows, covert actions, and tough bargaining rule decision-making processes. By attenuating structural misalignment, the promoter can mitigate the risk of potential schism with extant members caused by the late slippages in the performance targets disproportional to the value added by late changes to the scope. As the performance expectations remain less unstable, the public's perception of the performance of the promoter improves. This in turn helps the promoter to gain more legitimacy for the scheme in the eyes of third parties.

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