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Complexity and Uncertainty: Problem or Asset in Decision Making of Mega Infrastructure Projects?

WILLEM SALET, LUCA BERTOLINI and MENDEL GIEZEN

Abstract

How should one cope with complexity and uncertainty in mega infrastructure projects? While rational theories tend to eliminate or reduce these unruly conditions, the authors of this article are in search of a different approach to deal with the characteristics of complexity and uncertainty proactively. Three theoretical reflections are introduced to explore possible solutions: (1) the change of institutions to address the problem of excessively simple structures for making decisions on complex projects; (2) the shaping of a learning environment in order to deal with uncertainty and emergent properties; and (3) balancing the generation and the reduction of a variety of policy options in order to select a limited number of feasible options and to bridge the strategic exploration and the operational processes of decision making. Informed by this conceptual thought, concrete pathways are developed and discussed by means of a case study of the construction of a high-speed railway line in the Netherlands.

Introduction

The planning of mega infrastructure projects epitomizes the tension between current planning approaches and planning objects that are subject to extreme complexity and uncertainty. The inadequacy of current approaches to the planning of mega infrastructure projects has been extensively documented in international literature (for example, Altshuler and Luberoff, 2003; Flyvbjerg *et al.*, 2003; Priemus, 2007b; Priemus *et al.*, 2008). However, there is rather less consensus on how to improve on this. The aim of this article is to start to investigate and establish the features of a planning approach more suited to the complexity and uncertainty that characterizes mega infrastructure projects. We begin by drawing up a definition of mega infrastructure projects and by identifying one particular type of mega project as the subject of our analysis: major routes such as international highways or railways. Projects such as these usually start with a single primary function (for example, the interconnection of several urban nodes on a line of infrastructure), but in practice can become very complex: sooner or later they have to deal with the emergence of different purposes and interests in an ever-changing and unpredictable context of possibilities and constraints. In the first part of the article, we identify the challenge of the inquiry: the characteristics and sources of complexity and uncertainty for these 'route projects'. Here, we will consider all the emergent, multifunctional characteristics of these projects, as their dynamic and multiple nature

This article builds on empirical research pursued in the framework of a global research program on decision making in mega infrastructure projects: the Omega Centre for the Study of Mega Projects in Transport and Development (Bartlett School of Planning at University College London). The programme is sponsored by the Volvo Research and Educational Foundations (VREF).

appears to be a key source of complexity and uncertainty. We then consider the changes to political and social conditions that commonly occur during the course of the decision-making process, meaning that the basic features of a project may be the subject of ongoing controversy. An example of a major route project will be outlined to illustrate the particular types of uncertainties and complexities that are associated with such projects, namely the construction of a high-speed railway line in the Netherlands, connecting the rail network of Belgium and France with Rotterdam, Schiphol airport and Amsterdam.

In the second part of the article we explore the characteristics of a planning approach that acknowledges these sources of uncertainty and complexity. We shall start with a theoretical reflection of three crucial notions: (1) the change of institutions (to enable innovation of established routines and the lock-in situations of tunnelled decision making); (2) the shaping of a learning environment (in order to deal with unexpected conditions and emergent properties); and (3) balancing the generation and the reduction of a variety of policy options (to enable recombination of policy options).

Based on these conceptual grounds, four pathways are identified and explored in more detail. These pathways establish how to deal with complexity and uncertainty in the strategic and operational parts of mega project decision making:

- framing the strategic mission of the project;
- mobilizing institutional capacity;
- identifying and implementing robust and flexible options to deliver the project; and
- creating a learning context to identify and select from a variety of options.

The implications of this approach will be illustrated by means of a case study of a new railway line in the Netherlands, the High Speed Line (HSL) South, designed to link Amsterdam, Antwerp and Brussels.

Sources of complexity and uncertainty in mega infrastructure projects

What are mega infrastructure projects? Mega infrastructure projects are often a loosely coherent accumulation of single elements framed as a single unitary package. Furthermore, mega infrastructure projects build on existing realities; they are not dropped into an empty world: certainly, in urbanized areas, there is a great deal of infrastructure already. New projects usually aim ‘only’ at restructuring what is already there, or at complementing existing networks. The most subtle interventions — relatively small in themselves but often with a huge impact — are the ‘acupuncture’ type of projects that aim to interconnect or to upgrade broken or incomplete networks of infrastructure. Everyone is familiar with examples of massive urban motorways that function sub-optimally because of a few, relatively small missing links, such as the missing parts of the ring road around Melbourne, or the still-absent link between a major national motorway in a small area of natural beauty between Delft and Rotterdam in the Netherlands. Well-chosen connections within and between different existing networks may therefore dramatically improve the total network quality of a region or a country. The Regional Metro System under development in Naples is an example: while it has very far-reaching network impacts, it can be characterized as a collection of ‘missing links’ rather than as a single ‘mega’ infrastructure project (Cascetta and Pagliara, 2008). Furthermore, even in the context of the construction of completely new projects it is not unusual to distinguish different compartments of policymaking or to group a number of differentiated and separated small projects under one umbrella, such as the Cultural Forum in Barcelona, which covers about ten completely different urban projects (including, but not consisting exclusively of, infrastructure projects), or the Erdberger Mais in Vienna, whose flag flutters over an even larger number of small projects (Salet and Gualini, 2007; Majoor, 2008). Finally, the boundaries of projects are usually not

clear-cut, and even when these are precisely defined at the beginning, they often appear to change during the processes of decision making because of often unforeseen interrelationships with other developments. The focus of this article is on large infrastructure projects and we propose that this focus is irrespective of whether the project in question is a new stand-alone infrastructure project, a combination of new infrastructure links, or part of an assemblage of different projects held together by an integrated strategic perspective. Although this article looks primarily at complexity of purpose and interest, and towards uncertainty on a secondary level only, the two concepts belong together. We consider complexity as the number and type of components and the number and type of relationships between these. Thus, an increase in complexity often means that it is more difficult to comprehend the effect of influencing one element; hence there is increased uncertainty. Put differently, uncertainty refers to the components, relationships and interactions we do not fully comprehend or of which we may not even be aware. Complexity and uncertainty are thus strongly related.

When considering the complexity of projects, a crucial question is whether such projects primarily have an infrastructural function or whether infrastructure is only part of a multipurpose development strategy. In this article, we will focus on projects with a primary infrastructure focus. We are interested in mega infrastructure 'route-type' projects, such as highways or railways. This is an important distinction because the context of social and political governance differs greatly in the two cases, as does the way in which such projects are organized. A project with a primary infrastructure focus is likely to be organized within the margins of one policy sector (for example, transport). Obviously, even then infrastructure projects are not immune to other relevant economic, social and environmental conditions. In addition, these projects will serve broader economic or social goals by improving the accessibility for different categories of users, while we need to take their environmental impact into account. Nevertheless, the crucial difference is whether the project is primarily organized as an infrastructure project or as part of an integrated reconstruction of an urban area. In the latter case, different types of interdependent aspirations (the planning of offices, housing, or cultural facilities and environmental aspects) have to be organized in a multifunctional manner (as in the Barcelona and Vienna examples cited above). The interdependency of completely different functions and completely different stakeholders requires project management that differs considerably from that of single-sector projects. Levels of complexity and uncertainty will also differ substantially in these two types of projects. In this article, we shall thus explore only route projects that are primarily set up as projects with an infrastructure scope. However, we shall observe that during the processes of decision making, projects tend to evolve into complex multipurpose affairs because of the increasing significance of 'secondary' effects in the political arena, such as in the social, economic and environmental dimensions. This changeability of function and meaning amid a dynamic social and political context is one of the most fascinating sources of uncertainty and complexity in mega infrastructure projects. A change in political commitment and social mood seems endemic in long-lasting trajectories of decision making. The development and realization of mega infrastructure projects can easily take 20–30 years. Within such a timeframe it is not unusual to have recurring rounds of decision making, each involving different actors. This is one of the reasons why the same controversies about the quintessence, aims and target area of a project may reoccur during later stages. A recurring issue in this context is that members of the population who will be affected directly by the project become alert only during the implementation stage, when the first outcomes have become clear and visible, and only then request a discussion of the basic premise of the project.

Ironically, when plans are framed as abstract and uncontested ambitions at the outset, they receive approval more easily (Salet, 2008). Years later, as implementation takes place, people turn their attention to the initial assumptions and simple goals with critical views and insist upon more complex goals. Accordingly, the problem is that the initial single-sector structure of the decision-making system tends to be too simple, and as

such it is not responsive and sometimes even counter-productive to the highly complex problems emerging throughout the process. One way to tackle these problems of complexity and uncertainty is through rigid measures to restore the 'rational', original project logic by de-emphasizing the social and political variety and restoring order via an instrumental setting of goal, means and output (see the many claims for rational and sequential trajectories of decision making, the speeding up of decision processes by hierarchical solutions, and so on). We doubt whether this quest for rational logic will be effective and responsive to the complex realities and emergent properties of mega projects. We are in search of alternative ways to make positive use of complexity and uncertainty. We ask ourselves how the awareness of complexity and uncertainty can be used to better anticipate and prepare for decisions via intelligent and pragmatic ways of learning. Before introducing this reflection and its strategic and operational implications, it is useful to illustrate the conceptual challenges in the real context of decision making on a major route project in the Netherlands — the HSL South.

An illustration: planning the HSL South in the Randstad

Fundamentally different views on the project characterized decision making regarding the HSL South in the Netherlands, a train route linking Amsterdam to Antwerp and Brussels. The case illuminates the kind of strategic and operational learning that a complex and uncertain reality might require. In this article, we focus on only one representative phase and aspect of the process, namely the selection of the HSL route in the Randstad, a highly urbanized area between Rotterdam and Amsterdam. The main source of information is the extensive reconstruction of the case made by the commission installed by the Dutch parliament to investigate decision making on mega transport projects (Tweede Kamer der Staten-Generaal, 2004b; see also Priemus, 2007a; De Vries, 2008).

Alternative routes between Rotterdam and Amsterdam were at the centre of the political and technical debate concerning the HSL South in the 1990s. Figure 1 shows some of the routes considered. Different strategic perspectives on the project goals and means emerged during the debate, of which three were pivotal: the first perspective was initially the only one; the second and third emerged during the decision-making process. The first, initial perspective revolved around the development of a competitive transport product for the international traveller. The second, emerging perspective concentrated instead on mitigating the route's local impacts in general and on preserving the landscape of the Green Heart (the central open area in the Randstad) in particular. The third, also emerging perspective focused predominantly on reinforcing the urban structure of the Randstad by improving connections between the main cities and on linking these cities to metropolitan areas outside of the Netherlands.

This multiplicity of strategic perspectives translated into a number of dilemmas. From a transport-development perspective, achieving the shortest travel times between the main centres of population (traffic generators) seemed crucial. This led to a preference for routes that would link Amsterdam, Schiphol airport and Rotterdam directly by going straight through the Green Heart (such as preferred route A in Figure 1). Voices for local-impact mitigation and landscape preservation argued instead in favour of routes outside the Green Heart, using existing infrastructure corridors (route D in Figure 1).

From a perspective of reinforcing the structure and position of the Randstad, the most important element was linking all main urban centres to the HSL South. This meant not only Amsterdam, Schiphol and Rotterdam, but also The Hague, the seat of the national government and many international institutions. This perspective was also based on a preference for route D. However, not all perspectives were equally strong. Although the transport perspective was the only option for a long time and was always preferred by the central government, the environmental perspective gained strength during the consultation process and became an effective counterweight to the transport perspective. The two perspectives eventually dominated the debate on alternative routes in the

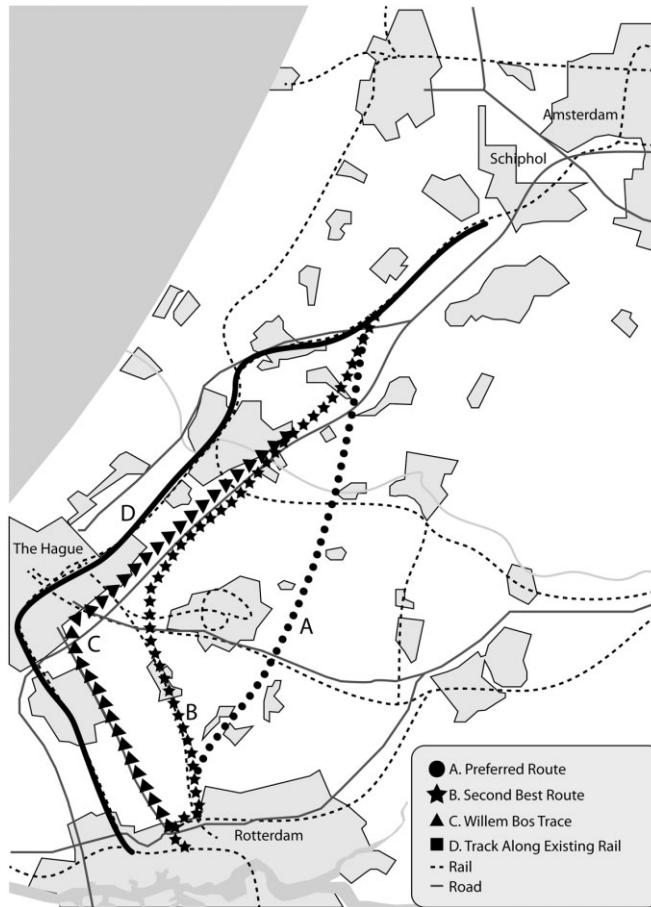


Figure 1 Alternative routes for the HSL South in the Randstad (source: adapted from Tweede Kamer der Staten-Generaal, 2004b)

Randstad. Each had a clear advocate: the Ministry of Transport and Public Works, and the Ministry of Housing, Spatial Planning and the Environment (VROM), respectively. VROM also supported the third perspective: fortifying the urban structure of the Randstad by improving connections between the main cities (the Randstad and its Green Heart are the main pillars of the Dutch spatial planning doctrine, after all). However, this perspective tended to be associated with a local lobby (most notably, the municipality of The Hague) rather than with a national interest. For a long time the different perspectives seemed irreconcilable, given that the most desirable route for one perspective was the least desirable for the other two, and vice versa. Complete deadlock appeared imminent on a number of occasions (Tweede Kamer der Staten-Generaal, 2004b; De Vries, 2008). After a long and turbulent process, and following direct intervention by the Prime Minister, a compromise between the first two perspectives was reached. The HSL would cut straight across the Green Heart, but a tunnel would be dug under its most valuable section, so as to reach a compromise between the first two perspectives. The only concession to the third perspective was a high-speed train ‘shuttle’ to The Hague, a service that would run a few times a day on conventional tracks branching out from the HSL line in Rotterdam.

The process that led to this compromise provides fascinating insights into the organization of strategic focus, into how actors learn, and into how redefining the strategic focus can generate robust and flexible policy options. Crucially, however,

the process also reveals how opportunities for identifying even more robust and flexible options, or a 'better compromise', can be missed. The final solution was, more than anything, a compromise between the first two perspectives (transport and environmental) that largely crowded out the third, namely the Randstad perspective. However, during the debate, alternative operational solutions combining *all three* perspectives were explored. The most debated of these were termed the 'Bos alternatives', referring to a civil servant who had developed a set of alternative route options on his own initiative in response to the apparent deadlock (the most prominent option being route C in Figure 1). The common denominator of these new alternatives was aligning the HSL with the existing A4 and A13 motorways (running south of Leiden and The Hague and east of Delft in Figure 1), which would achieve still-competitive travel times, avoid the Green Heart *and* create a fully developed station in The Hague.

As a governmental commission confirmed, the 'Bos alternatives' were a good second best option from *all three* perspectives (Tweede Kamer der Staten-Generaal, 2004b: 82). Because they were new ideas, developed in reaction to emergent dilemmas and the threat of a deadlock, they had hitherto not been included in the official route selection procedures (represented by the other routes in Figure 1). Their evident potential and the very considerable public support they enjoyed almost instantly (including a majority in parliament) ensured their later inclusion in the procedure. However, and this is a crucial point, this procedure was not followed in a way that allowed their full exploration because — it was contended — doing so would have produced unacceptable delays in the administrative and public consultation procedures. The decisive argument for discarding the Bos alternatives was thus not so much substance but rather procedural matters, or what might be termed the 'institutional tunnel'. The same procedural argument would also later be used to advocate 'not to learn' from other crucial but emerging insights (Tweede Kamer der Staten-Generaal, 2004b; Bertolini, 2010). In retrospect, the initial choice of route seems not to have ever been seriously questioned. Mitigation measures were accepted as a necessary price to pay on the way to implementation, but reconsideration of the original choice was never a real option. Whatever the potential of any alternatives, they would always be too late. Besides, the compromise route appears to have been a sub-optimal choice in many respects (Priemus, 2007a; Bertolini, 2010) and one that could not have adapted to newly emerging insights, whatever the breadth of consensus (Tweede Kamer der Staten-Generaal, 2004b). In this sense, the HSL South does not seem to differ much from mega projects elsewhere (Altshuler and Luberoff, 2003; Flyvbjerg *et al.*, 2003). The key questions are how to improve on these characteristic problems of mega project decision making; how to enlarge the opportunities for learning that are overlooked in current conventions; and how to recognize emerging complexities and uncertainties and find ways to cope with them. We turn to these questions in the remainder of this article.

Conceptualizing the responsiveness of planning

In search of a planning strategy that might be more responsive to these questions we first need to reflect on some crucial assumptions of strategic planning. The three conceptual reflections that follow serve to underpin our argument for a new style of strategic planning in mega infrastructure projects as a form of intelligent and pragmatic learning: (1) the assessment and change of institutions; (2) the shaping of a learning environment; and (3) balancing the generation and reduction of a variety of policy options.

We shall use these reflections as starting points for elaborating operational guidelines in the next section.

The change of institutions

Coping with complexity and uncertainty in mega projects never occurs in the blank context of free and rational choice. The procedures of decision making are nestled in customs, conventions, formal rules and patterns of social norms (Altshuler and Luberoff,

2003). Institutional conditions empower and enable certain ways of dealing with complexity and uncertainty while blocking others. Our question is how to establish a more open learning attitude. Institutional theories devote a great deal of attention to the constraining impact of *path dependencies*. Institutional economists indicate how sub-optimal procedures may become dominant because of the high transaction costs of institutional change (David, 1985; Arthur, 1989; North, 1990; Simmie, 2001). Pierson (2000) investigated similar sub-optimal path dependencies as expressions of asymmetric political power. The ‘tunnelling’ of decision making in major route projects may be analysed as an expression of characteristic *lock-in situations*. However, in dealing with institutions it is also important to consider the *changeability* of these conditions, not only at abrupt ‘critical junctures’ but as part of regular planners’ attitudes. Complex projects frequently require the establishment of ad hoc forms of organization and deliberation in order to escape the rigidity of existing routines and to find new common denominators. These changeable processes may lead to new institutional meanings arising. Institutions always carry meaning of past experience but this meaning evolves permanently by assessment and reassessment in new practical circumstances: institutional norms acquire new meaning *in* experiences of action. Thus, we do not analyse institutional patterns as *fixed* and *external* constraints, nor as completely *a priori* to action (Hall and Taylor, 1996). Institutional meaning has to be internalized in the minds of participants in order for it to become effective. In other words, we are not interested in the historic and external institutional constraints but in their actual institutional assessment and reassessment: that is, in the *transformational potential* of institutions (Dembski and Salet, 2010). In order to analyse the transformational potential it is crucial to investigate how different or conflicting preferences in the project are dealt with. Are conflicting preferences avoided and screened off from the ‘relevant options’ of decision making or are conflicts used to improve deliberation about alternatives? As uncertainty and complexity of projects hold a great deal of political and financial risk, addressing conflicting views is often avoided in practice and institutional innovation is resisted. However, a neglect of potential synergies of conflicting views may harm the substantive relevance of the outcomes, as the HSL South case illustrates. It is not easy to deal with conflicts; they may be irreconcilable (Rein and Laws, 2000). It is worth noting that planning cannot solve all conflicts, but the art of planning is very well suited to identify innovative solutions that might bridge different views. Focused on action, planning requires actors to advocate feasible options in line with their principal values. Even if values are irreconcilable, the consequences of different values and options can still be compared and innovative solutions identified.

The shaping of a learning environment

The second reflection is closely related to the first, namely seeing decision making as a process of *learning* and *experiencing*. The learning dimension has been explored in detail in the context of American pragmatism (for a recent review, see Healey, 2009). According to pragmatist thought, we do not need perfect certainty to proceed with planning. John Dewey, one of the founding fathers of pragmatism, went even further by considering the quest for certainty of knowledge itself as one of the main obstacles to intelligent policymaking (Dewey, 1960). Attempts to achieve certainty of knowledge would result in a sterile collection of cognitive knowledge, devoid of experience and action. Dewey radically toned down the ‘spectator view of knowledge’. As a dedicated politician himself, he fully realized that in the practice of decision making and organizing of collective action, more dimensions of ‘knowing’ are at stake than the pure cognitive knowledge of expert systems. He particularly highlighted such dimensions as ‘reflection’, ‘values’, ‘experience’ and ‘emotions’. He further ascertained that human knowledge is always incomplete and imperfect and that, for this reason, the knowledge of planning subjects *per se* is far less complex than the planning practices they are engaged with. This insight led him to conclude that one cannot cope with complexity and

uncertainty by collecting even more knowledge beforehand from an outside spectator position, but that the real meaning and useful value of knowledge can only be learned by trying and probing it *in* processes of experience (Dewey, 1964). This brings us to the crucial notion of the sociology of knowledge, namely that knowledge is related to context and is situational. Sociologists may have different notions of the definition of situational context (it is usually a rather ‘ad hoc’ context in American pragmatism and a more ‘structural’ and ‘historic’ context in European roots of sociology of knowledge) but the notion of situational knowledge does provide a clue on how to cope with the problems of complexity and uncertainty (Rittel and Webber, 1973; Rorty, 1982). The basic idea is that knowledge constantly becomes richer and more useful in processes of experimentation. As a consequence, processes of decision making express a clear intention to proceed down a specific path but the intention is to remain sensitive to modification. Decision making has to be organized as *learning processes in practices* instead of the implementation of solutions given *a priori*. Social facts and values are always subject to different valuations that cannot be reduced to the same denominator. Social facts and values can never be defined unequivocally. However, they can still be unified. This actually happens time and again in manifold daily practices through *action* (Dewey, 1964). Action causes a *certain* trajectory to be followed because one particular complex and irreducible array of possible options available is being experienced. Thus, the seemingly irreducible complexity of cognition is reduced by action, which actually creates a new practical situation that cannot be known completely and unequivocally, and eventually has to be followed by new action and experimentation.

The generation and reduction of variety

The third reflection concerns the delicate balancing of the *generation* and the *reduction of variety* of policy options. As mentioned above, the way to deal with complexity and uncertainty is institutionalized in certain ways, and has to be experienced through action-based learning. However, processes of institutionalization and experience do not always provide the optimal combination of generating a variety of policy options from which to choose, while reducing their number to a ‘manageable level’ to aid strategic and intelligent decision making (Ashby, 1956). The absolute essence of intelligent decision making is to pay tribute to both parts of the process (De Bruijn and ten Heuvelhof, 2004).

This brings us to one of the most stubborn problems of decision making in mega infrastructure projects, namely the risk of mismatches in generating and reducing the variety of options. One of the most frequent findings in empirical studies on decision making in mega infrastructure projects is that decision-making processes are organized in a manner that is far too reduced to enable adequate decision making on complex issues (see, for example, Priemus, 2007a). Highly *complex* mega infrastructure projects are frequently treated as *simple* processes of decision making, risking not only the occurrence of errors but also the neglect of the strategic potential of alternative options and the potential offered by recombination and enrichment with other trajectories of policymaking. This risk is frequently present in hierarchical and unitary settings of decision making and in ‘tunnelled’ forms of framing and project organization (Swyngedouw *et al.*, 2002). However, in order to proceed, options have to be limited. During the Dutch parliamentary enquiry, both sides of the dilemma were poignantly summarized by W. Korf, project director of the HSL: ‘The apparently logical sequence — first demonstrate the usefulness and necessity [of a project] and then articulate and implement the decision — does not hold. The usefulness and necessity of a project will continue to remain a matter of discussion. At some point, however, a decision must be taken whether to sign the contracts or stop altogether’ (Tweede Kamer der Staten-Generaal, 2004a: 140). Adequate solutions to this dilemma thus require a delicate balance between generating and reducing variety in both the strategic and the operational realms of decision making, or, in other words, a balance between *redundancy* and *parsimony* of decision making (Scholl, 2005). Instead of tunnelling the

process of decision making into narrow frames of thought and action, an adequate level of *strategic redundancy* (that is, a reservoir of alternative options) is required in order to enable recombining the paths of decision making in (frequent) cases of unforeseen circumstances (Landau, 1969; Low *et al.*, 2003; Sagan, 2004). At the same time, *parsimony* (that is, the reservoir of constraints in practice) is needed in order to proceed with a certain path of action.

Strategic and operational learning

In the further elaboration and concretization of our planning approach it is important to distinguish between the strategic and the operational levels of decision making (Miller and Lessard, 2008). At the strategic level a wide perspective on the mid-term or long-term future is framed progressively, both with respect to the substance of the project and its organization in order to keep a vital and shared mission in mind to inform decision makers in the turbulence of day-to-day decisions. At the operational level concrete decisions are made along a controlled but relatively open, step-by-step trajectory. These two distinct levels fulfil complementary functions; the optimal interaction between them is framed as 'strategic instrumentalism' (Etzioni, 1986). In practice, there are different ways to organize this interaction. Usually, a project-management structure is established by directly responsible agencies to manage a chain of operational decisions. Strategic deliberation may be established within this project-management structure or it may be arranged beyond the specific setting of the project, for instance in a more general urban or regional platform of strategic planning. In the case of mega infrastructure projects it should be organized within the structure of the particular project. However, under tight financial and procedural conditions, the level of strategic thinking and acting often tends to be rather thin (Flyvbjerg *et al.*, 2003; Rodriguez *et al.*, 2003). We consider it crucial to organize the interaction between the strategic and the operational levels as a 'disjointed linkage' by establishing a diverse and multidisciplinary strategic board *at a distance* from daily project management. It should incorporate and involve a variety of views (by organizing stakeholder meetings, and so on) and evaluation of the project not only at the beginning but at regular intervals to monitor progress. Although it is difficult to prevent powerful actors from influencing the selection of the commission, transparency should prevent an unbalanced strategic board. In the next section, guidelines are prepared for both levels of decision making.

The aim of the processes of strategic decision making should be (1) to frame and reframe the *strategic mission*; and (2) to mobilize *institutional capacity*.

The aim of the processes of operational decision making should be (3) to identify and implement *robust and flexible options*; and (4) to create a *learning context* for the generation and selection of such options.

Framing and reframing the strategic mission

When considering the innovative potential of institutions, the main challenge is how to frame and reframe the strategic mission of a project. In principle, the strategic level of decision making is the level at which the links between multiple project goals and their effects should be explored. Framing and reframing has to take the complexity of the project into account. It requires consideration of consequences that are not directly tied to the functional purpose of an infrastructure project. For instance, one should not only focus on the infrastructure effects of a new railway but consider ancillary interactive effects on the environment, economic development and settlement patterns. The shift from a narrow, functional, instrumental goal to a more complex set of interaction effects tied to multiple goals creates *strategic ambiguity*. However, strategic perspectives on mega infrastructure projects are often narrowed to simple frames of functional goals (the technical routines

and norms at the ministry responsible for the infrastructure, political specialists, economic interests of producers, operators and organized consumers of specific infrastructures). This also happened to be the case in the development of the HSL South.

The intriguing question in the HSL South case is why an authoritative combination of the different goals — in particular the Bos alternative — did not emerge at an earlier stage. Obviously, political preferences played a crucial role here. At the start of the project, its mission was politically defined as a transport infrastructure challenge: connecting the national railway with the European high-speed network and improving the interconnectivity of Schiphol airport. Thus, the functional goals (providing the fastest connection) prevailed from the very beginning. The environmental alternatives (avoiding a route through the Green Heart) entered at a later stage as counter-strategies. These alternatives resulted from legal requirements (the environmental impact analysis) and from the growth of the political left. The cabinet eventually decided on a compromise between transport and environmental objectives. The third relevant objective (the spatial improvement of the Randstad) did not receive political priority because it was considered a ‘local’ lobby. In the final stage of the project, parliament showed interest in the alternative option but it was too late for that option to become effective. Such a reduction of alternatives is often observed in complex projects, not only as a result of political preferences but also because of a reluctance to deal with the political and financial risks of the uncertainty of possible outcomes (Swyngedouw *et al.*, 2002; Salet, 2008). However, complexity strikes back if it is neglected: it results in counter-productive impacts on further decision making. In the Netherlands, all mega infrastructure projects in the past 20 years suffered from this type of insufficient institutional reflection on strategic principles and from the ensuing political disputes over environmental impacts, social impacts, spatial organization and even financial and economic impacts (Tweede Kamer der Staten-Generaal, 2004a; Priemus, 2007a). It seems that the structure for strategic decisions was not prepared to learn how to combine different rationalities. The planning ministry eventually had to learn from the bitter experience of controversy and from repeated readjustment at various stages of decision making.

The definition of the strategic mission of a project should therefore be open enough to enable the recombination of multiple objectives and their interaction effects at different stages of the project. The term ‘strategic mission’ has a specific meaning in this context. It is considered a ‘sense of direction’, something different from defining the end terms of an instrumental and unequivocal objective. A strategic mission reflects the tension and interdependence of different values and interests. It sets priorities by weighing up different values and recognizing the tension of (conflicting) underlying values, while maintaining the quality of strategic ambiguity to enable new ways of operational concretization during the decision-making process. Conversely, narrowly defined instrumental objectives at the start of a complex and very uncertain project do not structure the process of deliberation; the project is likely to get caught in its own web. The three basic deliberative forces in the Dutch case (infrastructure, environment and urban development) were never accorded the same level of deliberation. The ideal attitude during the planning stage would have been an open, explorative attitude that reflects a willingness by committed and entrepreneurial participants to share a mission, to consider different combinations of basic principles and to adapt to different, evolving social and political contexts.

Mobilizing institutional capacity

Framing has two dimensions: it requires not only the definition and redefinition of the strategic mission of a project, as discussed above, but also inter-organizational empowerment in line with this mission. In practice, the *organization* of this action framework is often not in line with the mission statement of the project (Schön and Rein, 1994; Salet, 2008). To generate institutional capacity at the strategic level in a context of

multi-actor and multilevel governance, interconnectivity needs to be organized. As major infrastructure projects increasingly integrate with economic, social and environmental development, the context of decision making has to become much more articulated. Instead of the traditional sector- and area-based — often government-led — planning approaches, current strategic planning in relation to mega infrastructural projects has become a challenge of co-production, interconnecting the institutional capacity of governmental agencies from different sectors and at different levels of scale and also of interconnecting various kinds of market and civic organizations. The organization of legitimate and effective action strategies within this multilayered context requires mobilizing and linking entrepreneurship in a broad range of domains. The organization of power needed to accomplish the mission of major infrastructure projects has become a relational phenomenon. Stoker (1995) labelled this change of power as the change of ‘power over’ into the relational and more enabling concept of ‘power to’. The success of leadership has become dependent on the quality of networking, and on the ability to involve different actors at different stages of the project.

Thus, a certain redundancy of sources of knowledge and channels of communication (through overlap in organization, duplicated forms of control, and so on) has become important in an evolving decision-making arena during which process participants with new interests and new rationalities enter the game. The configuration of policy actors must have a high enough degree of freedom to enable recombination of policy arrangements when conditions change.

In major infrastructure route projects, organization is usually led by agencies or consortia with the strongest interest in the successful realization of the primary functions of the project. This could be the transport ministry, the national railways, or a private-sector consortium. There is nothing principally wrong with this organization principle (Coleman, 1990); it makes sense that a watchful agency actively encourages the progress of the project — by resolving bottlenecks and by continuously searching for solutions and mobilizing new resources. Furthermore, such an approach may allow the lead player to internalize negative external effects, for instance by negotiating with neighbourhood associations, consulting with environmental groups, buying out litigants, and so on (Savitch and Kantor, 2002). However, there is an obvious risk that the scope of the project will be narrowed by the project’s selective management and that those involved fail to learn from the phenomenon of controversy and opposition (Flyvbjerg *et al.*, 2003; Rodriguez *et al.*, 2003).

The case of the HSL South demonstrates this risk. The leading Ministry of Transport was not responsive to the emerging secondary effects of the project (on the environment and urbanization). Strategic power was organized hierarchically instead of through interrelational leadership. This produced sub-optimal results. The problem in cases like this one is not that the operational decisions are made by the central management. The problem is that interaction between the operational steps and strategic reflection falls short. In order to meet the challenges of complexity and uncertainty adequately, deliberation on a project’s strategic mission has to be arranged at various intervals throughout the project. Strategic reflection should not be hierarchically concentrated on the centrally involved project management. Rather, it should be organized as relational leadership by engaging other actors and rationalities in the core group that is involved in strategic exploration. It is crucial to organize platforms of reflection and advisory boards that are authoritative and independent from daily management and bring different backgrounds and expertise to the project.

Identifying and implementing robust and flexible options

The understanding of what the project should and could be is likely to evolve during the course of the decision-making process. Changes are intrinsic to the very nature of mega infrastructure projects and, crucially, the details of the changes are by and large not predictable. Awareness of the system-wide implications of the project and perceptions of

its functional meaning also evolve. For instance, what was originally thought of as a transportation project may become an urban-development or a landscape-preservation project too, as was the case with the HSL South. As the perception of the nature of a project crystallizes, opportunities for synergy emerge, as do threats of conflicts with other developments. Making the most of these opportunities for synergy and adequately managing conflicts requires a degree of sophistication and adaptability in the project strategy and organization that typically proves very difficult to achieve (because of the many path dependencies in the project-organization and decision-making procedures). Accordingly, opportunities for synergy are lost, and conflicts tend to be solved on a rather ad hoc basis. Because of the very long timespan of the process of a mega infrastructure project, changes in social and political conditions are inevitable. To respond to these changes, new decision-making rounds are often started repeatedly, leading to an anachronic situation in which, for some, it is always 'too late to start a discussion', while for others it is always 'too early to take a decision'. The resulting impasses tend to be resolved by ad hoc opportunistic compromises rather than by a new synthesis, if they are resolved at all. The HSL South case poignantly illustrates all this, as do experiences elsewhere (see, for example, Altshuler and Luberoff, 2003).

What should be done to cope with this intrinsically *emergent* nature of the challenge of mega infrastructure projects? The most common approach tries to reduce this complexity and uncertainty by simplifying the decision-making process, that is, by narrowing the scope, speeding up procedures and limiting the involvement of those whose interests are affected. However, the inherent complexity and uncertainty of the project will often lead to this approach backfiring. Furthermore, in pluralistic, democratic societies such simplification is not even feasible. More often, then, complexity is dealt with 'marginally' as it becomes manifest (for example, through the accumulation of measures to mitigate adverse local impacts). However, the opportunities that a new situation might provide are therefore lost. Moreover, marginal solutions alone will inflate costs, as they simply add new elements to aspects that have already been budgeted for. Local-impact mitigation costs account for a substantial proportion of cost increases (Troin, 1995; Altshuler and Luberoff, 2003; Tweede Kamer der Staten-Generaal, 2004a). We propose instead an acceptance of the complexity and uncertainty of mega infrastructure projects and their unpredictability, and thus the emergent nature of opportunities and threats. This fundamental acceptance would redefine the challenge as one of identifying *robust* decisions and actions; that is, decisions and actions that are able to perform well in a variety of future technological, social and political conditions (that cannot be fully anticipated). In the case of the HSL South, the Bos alternatives were interesting precisely because they held this promise of robustness. At the same time, acceptance of complexity and uncertainty would require preserving *flexibility* in the decision-making and implementation process — in other words, the possibility to take decisions and implement actions at a later date when more is known about the relevant project conditions. In the HSL South, this would have meant postponing final decisions regarding the route as far as possible so that better alternatives could emerge from debate. These are the core principles which underlie planning and management approaches that build on the recognition of the unpredictability and uncontrollability of the outcome, and these are slowly being recognized and explored in a growing variety of fields (see, for example, Holling, 1978; Walters, 1986; Dietz *et al.*, 2003; Lempert *et al.*, 2003; Friend and Hickling, 2005; Bertolini, 2007).

Creating a learning context

How, then, should robust measures be identified? How should flexibility be preserved? Robust measures acknowledge the inevitability and incommensurability of differences; that is, differences in the interpretations of the subject matter of the mega project, and differences in the conditions (in particular social and political) surrounding its development. Moreover, robust measures can cope with these differences rather than

attempting to overcome them or assume they will be solved by some external force. In the HSL South case, the Bos alternatives seem to be an example of such robust measures. They imply the symmetric identification of measures that are *not* robust, as they contradict potential project interpretations and conditions, and thus the need to leave options open, or preserve flexibility. In the HSL South case all other route options seem less robust, as they neglect alternative definitions of the problem. Accordingly, identifying robust measures implies engaging with a *variety of views* of what the project and its surrounding conditions could and should be, and to do that in a phase in the process during which there is still scope to alter the course more than marginally. Such different views — and the different actors proposing them — have to be proactively solicited and made to interact with each other in order to identify potential problems and solutions and find common ground. Only when views are sufficiently contrasted to reflect the multiple implications of a project can the common ground be robust. This does not mean that it is always easy or even possible to identify robustness and preserve flexibility. After all, infrastructure is by its very nature irreversible to an important degree. However, there should be a proactive quest, and when unfeasible, awareness of the risk taken should be present, monitoring of evolving conditions should be in place and hedging measures should be identified (Bertolini, 2007; Marchau *et al.*, 2008). The project organization should therefore continuously probe the context, solicit different views and seek confrontation with different actors, as already mentioned under the section on mobilizing institutional capacity.

In this sense, the approach is similar to that of (re-)framing approaches (Schön and Rein, 1994; Rein and Laws, 2000) and to other approaches that deal with situations of deep-seated conflict. However, the irreversible nature of mega infrastructure projects must also be recognized. This is not simply a matter of involving different interests and views — as in a naïve interpretation of collaborative planning theory — but also of gearing such involvement towards the identification and implementation of the complex web of legal, financial and technical measures that can lead to the project being materialized over time while at the same time allowing future options to be kept open. This is a huge professional task that is only now being explored in, for instance, the application of real option approaches to cost-benefit analyses or of systems-engineering approaches to project design (Brand *et al.*, 2000; Kennisinstituut voor Mobiliteitsbeleid, 2007; Miller and Lessard, 2008), along with the investigation of new types of legal, financial and technical arrangements that these new approaches would require. It is also a huge political task, as it requires the redefinition of what public debate should be about, namely, not so much ‘one project’ but rather a set of ‘conditions’ to allow several, as yet undefined ‘different projects’ to be identified and implemented in stages (for example, in the case of the HSL South, not only an infrastructure project, but also an environmental and urban development project). Finally, it is a huge organizational task, as it requires project organization that can adapt constantly (with different goals, means, structures, activities, people) as the nature of the project evolves, and without losing a sense of direction. A learning context thus has to be created that enables this task to be done and provides the opportunity to generate and select options throughout the whole process.

Discussion and conclusions

The route of opportunistic compromises now characterizing mega project decision making appears to lead to sub-optimal outcomes (see also Altshuler and Luberoff, 2003). In response to this challenge we explored the potential of four alternative, complementary pathways that could have led to better outcomes. None of these pathways present easy answers. Mega infrastructure projects are irreversible to a considerable degree, a characteristic that inevitably affects the decision-making process. Still, the pathways may provide a focus for the analysis of the decision-making process and help

in the search for improvements. We realize that there are always specific power relations at play, especially in such complex projects. However, to bring the analysis of these relations to a level that would do justice to them would require a separate article in which to move from abstract concept to empirical data, and back to abstraction. Therefore we chose to focus on these four pathways.

As far as the specific context of the case of the HSL South is concerned, the Dutch parliamentary enquiry advocates a more thorough, divergent and transparent exploration of alternatives in the initial phases of the process (Tweede Kamer der Staten-Generaal, 2004a; see also Priemus, 2007a). This would guarantee that more informed choices would be made at the beginning of the process. Flyvbjerg *et al.* (2003) suggest a possible additional approach directed primarily at increasing stakeholder accountability and public awareness of the risks. This approach would ensure that risks are distributed more evenly and that more effective ways of managing them are identified. Although all of this is important, it should also be acknowledged that this approach does not eliminate the problems of complexity and uncertainty discussed in this article. Accordingly, both the exploration of alternatives and the assessment of risks cannot be carried out once and for all because social and political conditions and views on policy options will keep changing, soliciting new solutions and placing existing ones in a different light. A complementary direction of improvement would thus require a more robust and flexible approach to project development and, through this approach, increase opportunities to translate the lessons learned into new decisions and actions.

Multiple, changing views on policy options are an intrinsic feature of mega infrastructure projects as they result directly from the unique sources of uncertainty and complexity that characterize them. The ensuing challenge does not seem to be how to overcome this but rather how to shape the interaction between actors in an evolving institutional context in ways that allow them to continue to learn while exploring the scope for joint action. We discussed reflective notions regarding the potential of *institutional change* when conflicting views are included in the decision-making process of a project and strategic ambiguity of the project mission enables new combinations in the following rounds of decision making; the *processes of learning*, which enables project teams to deal with emerging realities; and the balancing of the need to *generate and reduce the variety* of complex decision-making processes in order to identify robust and flexible solutions.

Using this reflective framework we identified four pointers on how to proceed in the complex and uncertain contexts of strategic and operational decision making. The first of these devices, the deliberate framing and reframing of the strategic mission, emerges as a core item in practices that neglect the relevance of dealing with the complexity of different interests and rationalities. In particular, in route projects with a primary focus on infrastructure function, the typical sector organization tends to overlook the rationalities of secondary effects (such as the environment and the social and economic forces of urbanization). Indeed, many projects stall in the tunnels of decision making because of their overt limitation to primary transport functions. Strategic action requires a positive harnessing of tensions and possible conflicts between different objectives. The same applies to the second device, namely the mobilization of institutional capacity. Making things work means arranging the co-evolution of social and political energies instead of triggering negative energy in those groups that are excluded from the processes of deliberation. Thirdly, we have argued that robust policy options need to be identified. Such options enable open and future decision making on matters that have not yet been settled, and thus preserve flexibility. Finally, in the selection of operational choices, an experimental attitude should serve as a guarantee for testing different options and creating a learning environment.

Our analysis of decision making in mega infrastructure projects made use of many classic conceptualizations and experiences of planning and decision making under conditions of complexity and uncertainty. Strategic embedding of substantive focus, mobilizing different energies, trying and probing action in a learning environment and

selecting robust options are not completely new principles. We tried to combine and update these old strategies in the context of mega infrastructure projects and — as was illustrated in the case presented — we concluded that it still appears to be very challenging in practice to meet the conditions of uncertainty and complexity in mega project decision making. A simplification of the decision-making structures, often advocated and practiced, does not seem to lead to adequate acknowledgement of these conditions. Instead we are left wondering how different and changing perspectives on policy options can be brought into interaction in ways that maximize the opportunities of strategic, focused practices of learning and acting. We proposed some general principles on how to do this but further articulation and testing of these remains a major undertaking.

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Résumé

Comment doit-on gérer complexité et incertitude dans le cadre de mégaprojets d'infrastructure? Tandis que les théories rationnelles ont tendance à éliminer ou à minorer ces circonstances incontrôlées, cet article recherche une approche différente pour aborder les caractéristiques de la complexité et de l'incertitude de manière proactive. Trois axes de réflexion théorique sont présentés: la transformation des institutions, pour résoudre le problème des structures extrêmement simples confrontées à des décisions sur des projets complexes; la configuration d'un environnement d'apprentissage, pour faire face à l'incertitude et aux nouveaux éléments; l'équilibrage entre génération et réduction des diverses possibilités d'action publique, afin de sélectionner un nombre restreint d'options réalisables et d'harmoniser recherche de stratégies et processus décisionnels opérationnels. À partir de cette réflexion conceptuelle, des voies concrètes sont développées et analysées à travers une étude de cas sur la construction d'une ligne ferroviaire à grande vitesse aux Pays-Bas.