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Navigating mega projects through complexity and uncertainty: strategic and adaptive capacity in planning and decision-making

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

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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 (e.g. Altshuler & Luberoft, 2003; Flyvbjerg et al., 2003; Priemus, 2007b; Priemus et al. 2008). However, there is much less consensus on how to improve on this. The aim of this paper 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 sort of mega project as the subject of our analysis: major routes such as international highways or railways. Projects like these usually start with a single primary function (e.g. 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 paper, 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, multi-functional characteristics of these projects, as their dynamic and multiple nature appears to be a key source of complexity and uncertainty. Second, we consider the changes to political and social conditions common during the course of the decision-making process, which mean 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 these projects. It is the construction of a high speed railway line in The Netherlands, connecting the network of Belgium and France with Rotterdam, Schiphol Airport and Amsterdam.

In the second part of the paper we explore the characteristics of a planning approach that acknowledges these sources of uncertainty and complexity. We will start with a theoretical reflection of three crucial notions:

- a. The change of institutions (to enable innovation of established routines and the lock-in situations of tunnelled decision-making);
- b. The shaping of a learning environment (in order to deal with unexpected conditions and emergent properties);
- c. Balancing the generation and the reduction of a variety of policy options (to enable recombination of policy options).

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;
- Creating a learning context to identify and select among a variety of options.

The implications of this approach will be illustrated with the case of a new railway line in The Netherlands, 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 lot of infrastructure already. New projects usually 'only' aim 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 much better characterized as a collection of 'missing links' rather than as a single 'mega' infrastructure project (Cascetta & 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 exclusively, infrastructure projects), or the Erdberger Mais in Vienna, whose flag flutters over an even larger number of small projects (Salet & Gualini, 2007; Majoor, 2008). Finally, the boundaries of projects are usually not clear-cut, and even when these characteristics are precisely defined at the beginning, they often appear to change during the processes of decision-making because of their often unforeseen interrelationships with other developments. The focus of this paper is on large infrastructure projects and we therefore propose that this is irrespective of whether the project in question is a new stand-alone infrastructure project, a combination of new infrastructure links, or is 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 more secondary towards uncertainty, the two concepts are kept together. They are strongly related to each other. 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 it is more difficult to comprehend the effect of influencing one element; hence, there is an increased uncertainty. Put it differently, uncertainty are the components, relationships, and interactions we do not fully comprehend or are even aware of. Complexity and uncertainty are thus strongly related.

Considering the complexity of these projects, a crucial question is whether projects have primarily an infrastructural function or whether infrastructure is only part of a multi-purpose development strategy. In this paper, 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 the project is organized. A project with a primary infrastructure focus is likely to be organized within the

margins of one policy sector (e.g. 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 having to take their environmental impact into account. Nevertheless, it makes a crucial difference 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 multi-functional manner (as in the Barcelona and Vienna examples cited above). The interdependency of completely different functions and completely different stakeholders requires project management which 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 paper, we will thus explore only route projects that are primarily set up as projects with an infrastructure scope. We will observe, however, that during the processes of decision-making projects tend to evolve into complex multi-purpose 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 to 30 years. Within such a time frame 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 those members of the population who are going to be directly affected 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 at the outset are framed as abstract and uncontested ambitions, they more easily receive approval (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, etc.). 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 a positive use of complexity and uncertainty. We wonder how the awareness of complexity and uncertainty can be used to better anticipate and prepare on 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: HSL South.

An illustration: planning the HSL South in the Randstad

Fundamentally different views on the project characterized decision-making regarding HSL South in the Netherlands, a train route linking Amsterdam to Antwerp and Brussels. The case illuminates the sort of strategic and operational learning that coping with a complex and uncertain reality might require. In this paper, we focus on just 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).

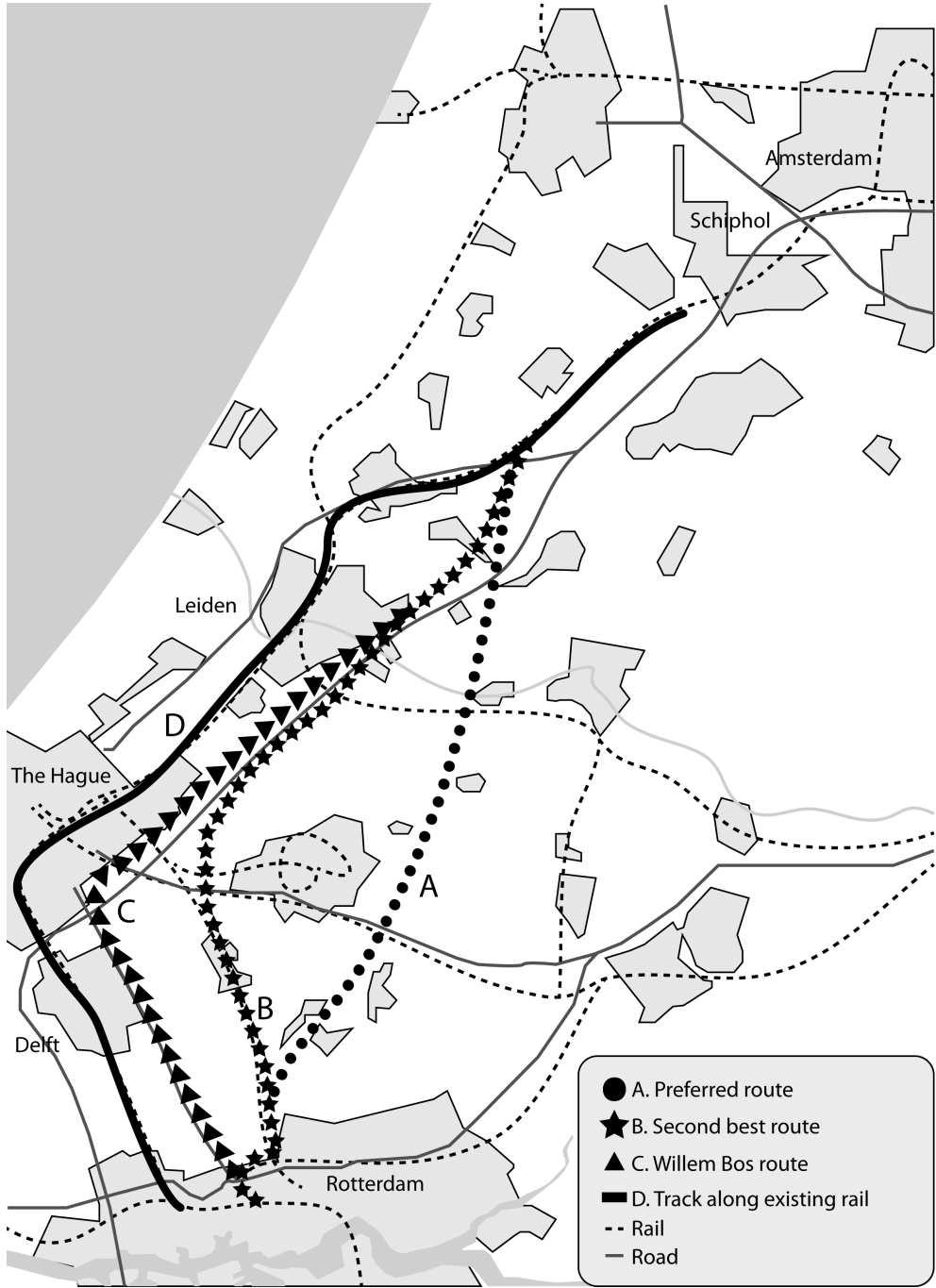


Figure 1. Alternative routes for the HSL-South in the Randstad.

Alternative routes between Rotterdam and Amsterdam were at the center of the political and technical debate around 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 local impacts in general and on the preservation of the landscape of the Green Heart (the central open area in the Randstad) in particular. The third and also emerging perspective focused pre-dominantly 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 the transport development perspective, achieving the shortest travel times between the main centers of population (traffic generators) seemed crucial. This led to a preference for routes that would directly link Amsterdam, Schiphol airport and Rotterdam by going straight through the Green Heart (such as the preferred 'A' route in Figure 1). The local impact mitigation and landscape preservation perspective argued instead in favour of routes outside of the Green Heart which used existing infrastructure corridors (the D route in Figure 1). From the perspective of reinforcing the structure and position of the Randstad, the most important element was the linking of all main urban centres to the HSL South. This meant not just 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 the D route. Not all perspectives were equally strong, however. Although the transport perspective was the only option for a long time and was always preferred by the central government, the environmental perspective acquired strength during the consultation process and became an effective counterweight against the transport perspective. These two perspectives eventually dominated the debate on alternative routes in the Randstad. Each had a clear advocate: namely 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 on 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 direct intervention of 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, reaching 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 running 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. As we have seen, the final solution was, more than anything, a compromise between the first two perspectives (transport and environmental), largely crowding 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, as a response to the apparent deadlock (the most prominent is the C route in Figure 1). The common denominator of these new alternatives was the aligning of 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, p. 82). Because they were new ideas, developed as a 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 did not take place 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 be later

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 does not seem to have ever been seriously questioned. Mitigation measures were accepted as a necessary price to pay on the way to its implementation, but re-consideration of the original choice was never a real option. Whatever the potential of alternatives, it was always 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, the HSL South does not seem much different from mega projects elsewhere (Altshuler & 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; how to recognize emerging complexities and uncertainties and find ways to cope with them. To these questions we turn in the remainder of the paper.

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 next three conceptual reflections serve to underpin our argument for a new style of strategic planning in mega infrastructure projects as a form of intelligent and pragmatic learning:

- a. The assessment and change of institutions;
- b. The shaping of a learning environment;
- c. Balancing the generation and the reduction of a variety of policy options.

We will use these reflections as starting points for the elaboration of operational guidelines in the next section.

Ad a. The change of institutions

Coping with complexity and uncertainty in mega projects never occurs in the blank context of free and rational choice. The routines of decision making are nestled in customs, conventions, formal rules and patterns of social norms (Altshuler & 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 lot of attention to the constraining impact of path

dependencies. Institutional economists indicate how sub-optimal routines may become dominant because of the high transaction costs of institutional change (David, 1985; Arthur, 1989; North, 1990; Simmie 2001). Pierson investigated similar sub-optimal path dependencies as expressions of asymmetric political power (Pierson, 2000). The 'tunnelling' of decision-making in major route projects may be analyzed as an expression of characteristic lock-in situations. In dealing with institutions, however, it is also important to consider the changeability of these conditions, not just 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. In these changeable processes, new institutional meanings may arise. 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. So, we do not analyze 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 re-assessment: the transformational potential of institutions (Dembski & Salet, 2010). In order to analyze 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 for better deliberation on alternatives? As uncertainty and complexity of projects holds a lot of political and financial risk, in practice the taking on board of conflicting views is often avoided and institutional innovation resisted. Neglecting the potential synergies of conflicting views, however, 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 & Laws, 2000). It is worth noting that planning cannot solve all conflicts, but the art of planning is very well suited to identifying 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.

Ad b. 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 (see for a recent review 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 just 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 a position of outside spectator 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 rather 'ad hoc' context in American pragmatism and more 'structural' and 'historic' 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 (Rorty, 1982; Rittel & Webber 1973). 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 valuation which 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 time 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.

Ad c. The generation and the 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 by action-based learning. However, processes of institutionalization and experience do not always provide the optimal combination of generating a variety of policy options to choose from, 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 the generation and reduction of variety of options. One of the most frequent findings in empirical studies on decision-making in mega infrastructure projects is that decision processes are organized in a manner that is far too reduced to enable adequate decision-making on complex issues (see e.g. 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). On the other hand, 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, p. 140). Adequate solutions to this dilemma thus require a delicate balance between the generation and reduction of 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 & 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 at the horizon in the turbulence of day-to-day decisions. At the operational level concrete decisions unfold in a controlled but relatively open, step-by-step trajectory. The distinct levels fulfil complementary functions; the optimal interaction between the two levels is framed as 'strategic instrumentalism' (Etzioni, 1986). In practice, there are different ways to organize this interaction. Usually, 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 these projects. 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 as a 'disjointed linkage' by establishing a diverse and multi-disciplinary strategic board at a distance from the daily project management. It should incorporate and involve a variety of views (by organizing stakeholder meetings, etc.), evaluating the project not just in the beginning but at regular intervals to monitor progress. Although it is difficult preventing powerful actors 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:

- a. To frame and reframe the strategic mission;
- b. To mobilize institutional capacity.

The aim of the processes of operational decision-making should be:

- c. To identify and implement robust and flexible options;
- d. To create a learning context for the generation and selection of such options.

Ad a. Framing and reframing the strategic mission

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 place where 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 not directly tied to the functional purpose of an infrastructure project. For instance, one should not just focus on infrastructure effects for 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, the political specialists, the economic interests of producers, exploiters and organized consumers of specific infrastructures). This also happened to be the case in the HSL South.

The intriguing question in the HSL case is why an authoritative combination of the different goals - in particular the Bos alternative - did not emerge in an earlier stage. Obviously, political preferences played a crucial role here. At the start of the project, the mission was politically defined as a transport infrastructure challenge to connect the national railway with the European high speed network and to improve the interconnectivity of Schiphol Airport. So, the functional goals (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 were instigated by legal requirements (the environmental impact analysis) and by the growing position of the political left. The cabinet eventually decided for a compromise solution between the transport and environmental objectives. The third relevant objective (the spatial improvement of the Randstad) did not get political priority because it was considered as 'local' lobby. In the final stage, the parliament showed interest in the alternative option but it was too late for that option to become effective. This reduction of alternatives is often observed in complex projects, not only as a result of political preferences but also because of the reluctance to deal with the political and financial risks of uncertainty about the possible outcomes (Swyngedouw et al 2002, Salet 2008). However, complexity strikes back if it is neglected: it results in counterproductive impacts for further decision-making. In the Netherlands, all mega infrastructure projects in the last 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 by the bitter experience of controversy and by the repeated readjustment at the various stages of decision-making.

The definition of strategic mission should thus be open enough to enable new re-combination of multiple objectives and their interaction effects in different stages of the project. The term 'strategic mission' has a specific meaning in this context. It is considered as a 'sense of direction', something different than 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 priority by weighing the different values, recognizing the tension of (conflicting) underlying values, yet also maintaining the quality of strategic ambiguity to enable new ways of operational concretization during the decision-making process. Conversely, starting a complex and very uncertain project with narrowly-defined instrumental objectives does not structure a process of deliberation: the project is likely to get caught in its own web. The three basic deliberative forces in the Dutch case (the infrastructure, the environment and the urban development) were never accorded the same level of deliberation. The ideal attitude during this stage would have been an open explorative attitude, reflecting 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.

Ad b. Mobilizing institutional capacity

Framing has two dimensions. It requires not only the definition and redefinition of the strategic mission of the 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 & Rein, 1994; Salet 2008). To generate institutional capacity at strategic level in a context of multi-actor and multi-level governance, interconnectivity needs to be organized. As major infrastructure projects integrate more and more 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 - and 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 sorts of market and civic organizations. Organizing legitimate and effective strategies of action in this multi-layered context requires the mobilizing and linking of 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 labelled this change of power as the change of 'power over' into the relational and more enabling concept of 'power to' (Stoker, 1995). The success of leadership has become dependent on the quality of networking, on the ability to involve different actors in 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, etc.) has become important in an evolving decision-making arena where during the process participants with new interests and new rationalities enter the game. The configuration of policy actors must have enough degrees of freedom to enable recombination of policy arrangements when conditions change.

In major infrastructure route projects, usually, the organization is led by agencies or consortia with the strongest interest in the successful realization of the primary functions of the project. This can be the ministry of transportation, 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, etc. (Savitch & Kantor, 2002). On the other hand, the obvious risk is that the scope of the project is narrowed by the project's selective management and that those involved fail to learn from the phenomenon of controversy and opposition (Rodriguez et al., 2003; Flyvbjerg et al., 2003). The HSL South case demonstrates this risk. The leading Ministry of Transport was not responsive to the emerging secondary effects of the project (with regards to the environment and urbanization). Strategic power was organized hierarchically instead of inter-relational leadership; this produced sub-optimal results. The problem in cases like this 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 adequately meet the challenges of complexity and uncertainty, deliberation on strategic mission has to be arranged at various intervals throughout the project. Strategic reflection should not be hierarchically centred around the centrally involved project management. Rather, it should be organized as relational leadership by involving other actors and

rationalities in the core group involved in strategic exploration. It is crucial to organize platforms of reflection and advisory boards, authoritative and independent from the daily management, and consisting of different backgrounds and expertise.

Ad c. Identifying and implementing robust and flexible options

The understanding of what the project should, and could, be is liable 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 becomes an urban development or a landscape preservation project as well, as was the case with the HSL South. As the perception of the nature of the project crystalizes, 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 which 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 time span of the process in a mega infrastructure project, changes in social and political conditions are inevitable. To respond to these changes, new decision-making rounds are often started over and over again, leading to an endemic 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 get resolved at all. The HSL South case poignantly illustrates all this, as do experiences elsewhere (see e.g. Altshuler & 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 process; that is, by narrowing the scope, speeding up the procedures, and limiting the involvement of affected interests. However, the inherent complexity and uncertainty of the project will often backfire. Furthermore, in pluralistic, democratic societies such simplification is not even feasible. More often, then, complexity is dealt with 'marginally' as it becomes manifest (e.g. through the accumulation of measures to mitigate adverse local impacts). However, the opportunities that a new situation might also provide are therefore lost. Moreover, marginal solutions alone will

inflate costs, as they simply add new elements to what has already been budgeted for. Local impact mitigation costs account for a substantial proportion of cost increases (Troin, 1995; Altshuler & 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 that of identification of 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 (which cannot be fully anticipated). In 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 – or, in other words, the possibility to take decisions and implement actions at a later date when more is known about relevant project conditions. In the HSL-South, it would have meant postponing final decisions on the route as far as possible, so that better alternatives could emerge from the 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 beginning to be recognized and explored in a growing variety of fields (e.g. Holling, 1978; Walters, 1986; Dietz et al., 2003; Lempert et al., 2003; Friend and Hickling, 2005; Bertolini, 2007).

Ad d. 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 development of the mega project. 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 during a phase in the process where there is still scope to alter the course more than marginally. These 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 the project can the common ground be robust. This does not mean it is always easy, or even possible to identify robustness and preserve flexibility. After all, infrastructure is by its very nature for an important degree irreversible. However, it 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 point b.

In this sense, the approach is similar to that of (re-)framing approaches (Schön & Rein, 1994; Rein & 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. It is not just a matter of involving different interests and views – as in a naïve interpretation of collaborative planning theory - but also of gearing such involvement to the identification and implementation of the complex web of legal, financial, and technical measures that can incrementally materialize the project while at the same time keeping future options open. This is a huge professional task, which is just beginning to be explored with, for instance, the application of real-option approaches to cost benefit analysis or of system engineering approaches to project design (Brand et al., 2000; Kennisinstituut voor Mobiliteitsbeleid, 2007; Miller & 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 the public debate should be about, namely not so much 'one project' but rather a set of 'conditions' to allow different, as yet undefined 'different projects' be identified and implemented in later stages (e.g. in the case of the HSL South, not just an infrastructure project, but also an environmental and urban development project). Finally, it is a huge organizational task as it requires a project organization that can constantly adapt (with different goals, means, structure, 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

All told, the route of opportunistic compromises now characterizing mega project decision-making appears to lead to sub-optimal outcomes (see also Altshuler & Luberoff, 2003). In response to this conundrum, 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 the search for improvements. We realize that there are always specific power relations in play, especially in such complex projects. However, to bring the analysis of these relations at the level that would do justice to them would require an separate paper where there is space 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 in 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 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 it does not eliminate the problems of complexity and uncertainty discussed in this paper. Accordingly, both the exploration of alternatives and the assessment of risks could not be carried out once and for all because social and political conditions and views on policy options will keep changing, soliciting new solutions and putting 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 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 enable 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 the 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, a lot of projects get stalled in the tunnels of decision-making because of their overt limitation to primary transport functions. Acting in a strategic way requires a positive use of tensions and possible conflicts between different objectives. The same applies to the second device regarding 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. Third, 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 the testing of different options and the creation of 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. The strategic embedding of substantive focus, the mobilizing of different energies, the trying and probing of action in a learning environment and the selections of robust options are not completely new principles. We tried to combine and update these old stratagems 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. Simplifying the decision-making structures, as often advocated and practiced, does not seem to lead to an 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 the further articulating and testing of these remains a major undertaking.

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