Public Decision-Making as Coevolution

Lasse Gerrits
Erasmus University Rotterdam, NLD

The main argument of this article is that public decision-making has an anthropocentric focus that lacks explanatory power. An alternative approach is suggested. This approach reframes decision-making as a process of coevolution between decision-makers and the system they attempt to govern. Coevolution can explain the occurrence of unintended, unforeseen and unwanted consequences of decisions. The framework is applied to analyze a case of planning port extensions in Hamburg, Germany, in order to demonstrate the workings of the coevolutionary approach to public decision-making processes.

Introduction

Public decision-making over physical systems often has an anthropocentric perspective. That is: it is (implicitly or explicitly) assumed that the decision-maker is in full control of the physical system. There are no issues with this approach as long as the physical system responds predictably. But often the responses are erratic, badly predictable and, sometimes, unfavorable. In such cases, people tend to blame decision-makers for taking the wrong decision. However, that ignores that decision-making take place in a capricious world, and that decisions are distorted because of the erratic behavior of systems. In order to analyze the complexity of decision-making, one has to assume a complex systems perspective as the point of departure. Such an analysis should take into account that causation is complex and changeable over time, and it should abandon the anthropocentric perspective for a coevolutionary revision.

This article argues that the concept of *coevolution* helps understanding the erratic nature of decision-making better than more traditional approaches. This idea is clarified through a case study of the extension of the port of Hamburg. The next section introduces this case study. The third section is dedicated to the introduction of the coevolutionary framework for decision-making that allows understanding the outcomes of the case. The conclusions are presented in the final section.

Planning Port Extensions

The Elbe provides maritime access to Hamburg in Germany, one of Europe's largest ports and an economic powerhouse. The port authorities (HPA) feel obliged to plan port extensions because this is perceived as the main strategy in order to stay ahead of the competition elsewhere in Europe. Hamburg seeks to increase the capacity among others by planning a new motorway from east to west (see Van Gils *et al.*, 2009). Another proposed measure to increase the port's capacity is to deepen the navigation channel of the Elbe River between the port and the North Sea. This section measures approximately 100 kilometers. Large cargo ships are too large to enter the port around the clock because of the shallow depth. They are obliged to wait until the tide is high enough to safeguard the depth under the keel. A deeper Elbe would allow these ships to enter port any time during the day. The Elbe has been deepened several times between 1900 and 2007. After the deepening in 1980, the port authorities and the Senate of Hamburg planned another deepening operation that was to be completed somewhere between 1995 and 2000. The planning process gained momentum during 1996, when this case study starts. Data was collected through interviews and document analysis. Twenty semi-structured in-depth interviews were conducted during summer—fall 2007 in Germany. Document analysis covered over 175 newspaper articles, policy documents and scientific publications published about the case. Newspaper articles were triangulated using multiple sources. A full list of respondents and all articles and documents is published in Gerrits, 2008.

When the planning process starts in 1996, it is hampered by fierce resistance from

many stakeholders such as environmental pressure groups and concerned citizens. The port authorities and the Senate are convinced that the deepening will benefit the region tremendously in terms of employment and prosperity. Opponents on the other hand argue that it adds marginally to economics growth and they fear that it comes at the cost of the environment, safety and quality of life. There is also opposition from the neighboring federal states Niedersachsen and Schleswig-Holstein. They are afraid that any damage to the environment has to be compensates by them rather than by Hamburg, since the Elbe runs through their territory.

Fearing the effects of public resistance on the planning progress, HPA and the Senate try to shield it away from public pressures and try to speed up the process as much as possible. The obligatory environmental impact assessment (EIA) is delayed but the operation gets the nod anyway in 1996, long before the EIA is published. The assessment arrives in 1997 and by that time the port authorities have already advanced their planning. The EIA indicates that the deepening can be carried out without major unfavorable consequences for the environment but a monitoring program will be established in order to monitor the effects of the deepening. While the EIA marks the start of the formal planning procedure, including the possibilities to object against the deepening, HPA announces that it will start to remove the first layer from the riverbed immediately, in what it calls a 'preparatory dredging' operation. Throughout the region, the stakeholders are infuriated because of this strategy.

When possible, HPA and the Senate try to settle the conflict through financial compensation. Other objections are more difficult to deal with. Niedersachsen and Schleswig-Holstein are forced to cooperate in the end. Many stakeholders submit complaints during the formal planning procedure. However, the organization that is to judge these complaints is the same one that plans the deepening and the complaints are brushed aside. It decides that these groups are illegitimate parties and therefore there is no obligation to respond to them. The preparatory dredging operation goes ahead, followed by the actual deepening operation and a concluding ceremony on December 14, 1998.

Pushing Forward a New Deepening

Much of the uproar fades away after the deepening. Niedersachsen senses that the growth in the cargo shipping will continue in the foreseeable future and plans the construction of a deep-sea terminal at Wilhelmshaven at the North Sea coast near the Elbe. The purpose of this terminal is to create additional capacity for the turnover of goods, especially for those ships that are too large to travel on the Elbe. Now it is the turn for Hamburg to be very concerned about a plan. It fears that the new port relatively nearby will draw ships away. Consequently, it starts talking about another deepening operation that could accommodate the largest ships destined for the future Wilhelmshaven terminal. The mayor of Hamburg manages to strike a deal with Niedersachsen that gives Niedersachsen its much-desired terminal because Hamburg promises to finance 20% of it in return for support for yet another deepening.

However, re-elections in the summer of 2001 herald a change in Hamburg, with the Christian Democratic Party (CDU) now heading the department dealing with the port and appointing Mr. Gunnar Uldall as its Senator. Uldall was strongly against the agreement between Niedersachsen and Hamburg and one of his first measures is to announce that Hamburg will not take up its 20 percent share in the deep-sea terminal project. Instead, he aims to deepen the Elbe as soon as possible in order to secure a potential market share that otherwise might come to Wilhelmshaven. He appoints a civil working group to investigate the possibility of conducting a new deepening operation. Although he says that Niedersachsen agrees with this move, Niedersachsen itself asserts that it has not. There is also fierce resistance from the stakeholders. Uldall pushes ahead with his plans and aims for a quick decision.

The civil working group, however, is less confident about the feasibility. They are struggling with the compensation measures from the previous deepening. Although

they have made suggestions on how to realize aquatic compensation, putting these ideas into practice proves to be very complicated. Compensation measures are therefore focused on the terrestrial dimension but this poses another range of problems. There are few spots along the river banks where room can be found for such compensation. This is a problem because compensation for the previous deepening is mandatory and because it could even get more difficult if a new operation is carried out. In the end, Hamburg argues that some of the observed physical changes to the Elbe cannot be contributed to the previous deepening operation anyway and should not be taken into account when debating compensation. In other words: compensation does not need to be as intensive as planned before. Despite all good intentions, compensation is deemed to be only a marginal success among the civil working groups and on April 4, 2002, Uldall announces that Hamburg will deepen once again, 3 years after the previous deepening. The civil working group releases a report in October 2002, stating that the deepening can be carried out without major unfavorable effects.

The planning of the new deepening goes ahead during the years that follow. The period is marked by a continuous exchange of views between all actors. HPA starts to organize meetings in the region to provide information about the next deepening. Uldall urges to publish a preliminary monitoring report. Some argue that it is not yet possible to observe any physical changes because morphological changes to the riverbed take around 10 to 15 years to appear. However, a rapport is published and the fact that it shows that there were no changes so soon after the deepening is announced as evidence that the previous deepening was without unfavorable consequences.

Away from the public eye, however, officials acknowledge that the previous deepening caused an increase in the tidal range (the difference between ebb and flood). There are also problems with sediment transport that may arise due to increased tidal velocity in the river. The new dredging works are not expected to require considerable reallocation of sediments but the changing tidal currents may cross this point of departure. Officials feel even more pressure to have a deepening without unfavorable effects because the river has become part of the EU Habitat Directive and this means that there is less room for modifications. Hamburg manages to exempt the port itself from the Directive, but other operations need an additional assessment.

Having passed this hurdle, Hamburg moves on to tackle the row with Niedersachsen and Schleswig-Holstein. Hamburg's mayor realizes that the states will push their port at Wilhelmshaven regardless of any support from Hamburg so he decides that it is more useful to support the port in exchange for support for the deepening. A document is signed and all actors promise not to obstruct each other. The next step is to get the societal groups to accept a deepening. To this end, a mediation process is established.

An Unpleasant Surprise

While the policy makers are working on securing a further deepening, they are suddenly faced with a major unfavorable physical change in the Unterelbe. Dredgers find that the amount of material dredged during maintenance operations in 2004 is considerably higher than during previous years (see Figure 1). Soundings confirm their observation, i.e., that the amount of sediments flowing in from the North Sea and accumulating in the harbor basin has suddenly increased from 4,5 million cubic m3 in 2003 to 9 million cubic m3 a year later. This comes as a major surprise to all actors. A small increase had been predicted in the EIA but no one foresaw this large of an increase. It poses a major problem for all proponents of the deepening.

The first of these problems are escalating costs arising from an urgent need to intensify dredging because sediments are now obstructing navigation in the port. The second problem is the lack of space to dispose of the sediments. Having no more space available within the city, Hamburg needs to turn to its neighbors but following the many rows with Niedersachsen and Schleswig-Holstein it does not gain any clearance to store the sediments within their territory. HPA therefore

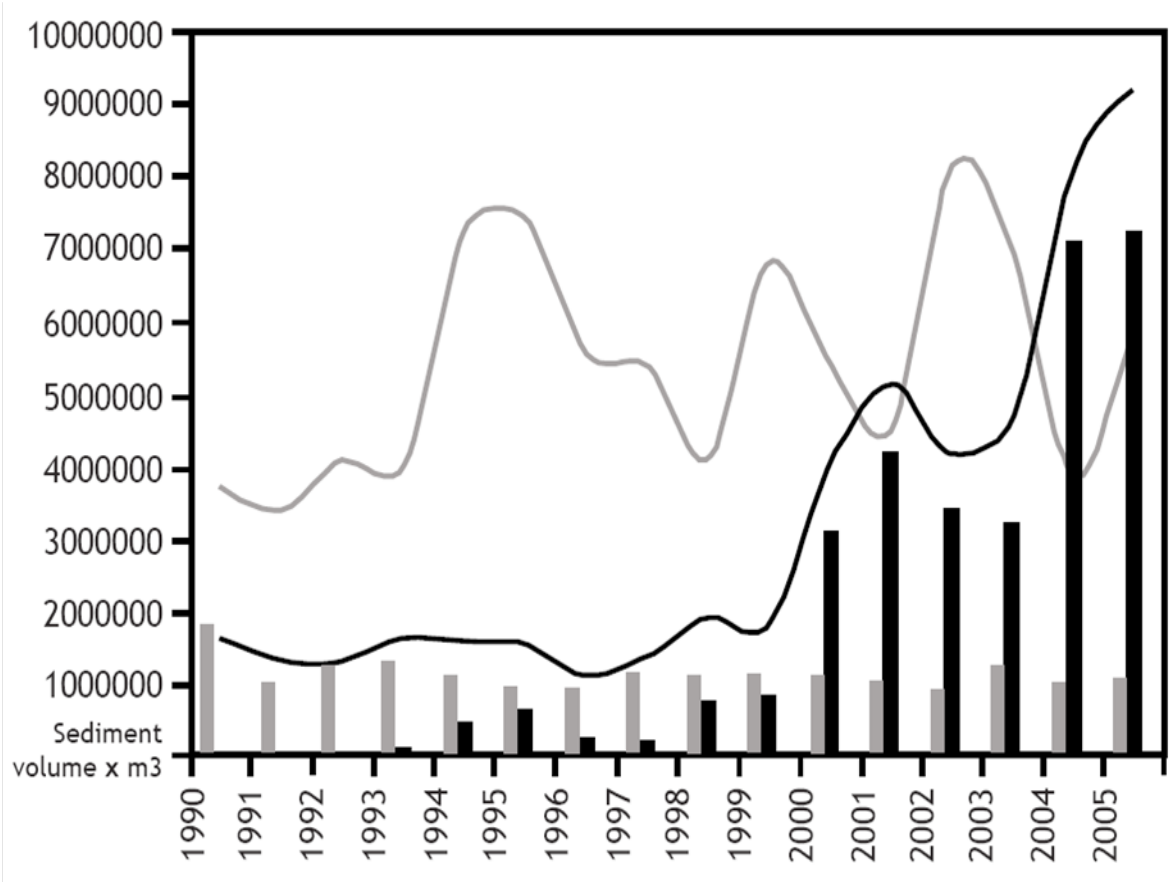

Figure 1 *Sediment accumulation in the Elbe between 1990 and 2005.*

The total volume of sediments is indicated by the black line. The total volume comprises sediments that are processed locally, e.g., storage, remediation (grey columns), and sediments that are dumped at the territorial borders of the City of Hamburg (black columns). The grey line indicates the fresh water discharge at Neu Darchau (Gerrits, 2008, adapted from Bundesanstalt fur Wasserbau, 2005).

chooses to go back to an earlier solution: to take the sediments to the border of their territory, dump them in the river, and hope that the tidal currents will then take them to the North Sea. This doesn't happen, as it is the North Sea where the sediments come from in the first place. Consequently, HPA has to dredge the port over and over again in an almost vicious dredging cycle.

Although it is very complicated to assess how each individual measure has contributed to this change, there are a number of mechanisms that can explain this sudden increase of sedimentation. It began prior to the most recent deepening and maintenance dredging operations have always been necessary. However, some officials acknowledge that the deepening operation has contributed tremendously to this development by altering the stable state of the river in such a way as to disproportionately accelerate sedimentation in the port.

The incident marks a change within the homogeneous group of officials preparing the deepening. At the one hand there are those who favor a new deepening and who are deeply concerned about the progress of their plans. They view the physical changes as a coincidence rather than a consequence of the deepening. At the other hand, there are people who start to think that the deepening of the river is not the best way for the future and the start pleading for a change of direction. The latter represent a minority view. But while officials debate the causes of the physical changes, there is ongoing pressure to do something about it—

if only because the accumulation of sediments crosses the reason d'etre of the deepening. The press in Hamburg is unanimous in their verdict. They state that the officials are blinded by their ambition to get a new deepening, consequently overlooking or underestimating the potential risks of doing this. They point at the monitoring program that was scheduled to run for an additional 10 years before a new deepening would be considered. With hindsight, the very early publication of the monitoring report was a poor move.

At first sight, one would agree with the local press. However, although there were some politicians who were certainly pushing forward with their case, there were also officials who were genuinely taken by surprise by the physical changes. One could then argue that the research for the deepening was faulty and that the inability to predict this change is down to the researchers' lack of knowledge.

However, this kind of thinking does not take into account the unpredictable nature of physical systems. Even the most elaborate studies and models are unable to capture this unpredictability to its full extent. This is problematic because uncertainty over future developments does not allow for the clarity that is required to make an informed decision. As stated by Otter in the context of coastal zones development: "a fully deterministic approach [as required in the political arena—LG] cannot handle the uncertainty related to the management of many environmental systems." (2000: 110). Taking this further, the actors themselves could be the cause of the developments that turn out to be unfavorable to them. One must bear in mind that physical systems are not passive. They respond dynamically and unpredictably to policy decisions, which could yield unfavorable results. One should move beyond the obvious explanations in order to understand the full complexity of decision-making processes.

Coevolution between Systems

The first step in understanding how seemingly sound decisions can lead to adverse effects on physical systems is to understand that decisions and the actors who make these decisions are an integral part of the chain of causes and consequences that drives physical change (Hooke, 1999; Turner, 2000). When a physical system on the one hand and decision-makers and public decision-making processes on the other hand both evolve through mutual interaction in an unpredictable way, this is a form of coevolution. Coevolution, its drivers and its consequences for decision making are the core theme of this article.

The term coevolution was coined by Ehrlich and Raven, who observed that groups of organisms evolved through reciprocal selective interaction (1964, in: Odum, 1971). While mutation can be explained by observing selection pressures on an organism from the environment, coevolution explains that this mutation in turn affects the environment of that organism. The explanatory power of coevolution for change is therefore situated in the pattern of mutual influence that can arise between organisms or, in the context of this research, between complex adaptive systems. The coevolutionary principle has emerged in other domains as well, although not always under the same heading. For a theory to have an evolutionary character, it should assume a directional tendency to change, whether by progression or regression, as well as explanatory mechanisms that drive this change, bearing in mind that these mechanisms are local rather than presumed universal (Sanderson, 1990). Sanderson states that there are a growing number of accounts that regard socio-cultural change as a result of coevolution between a biological system with genetic mechanisms and a cultural system with non-genetic mechanisms. This introduces the idea that biological or physical systems and social systems can be considered to be intertwined in a coevolutionary relationship in which there is reciprocal selection between these seemingly incompatible systems.

Coevolution and Decision-Making

Norgaard (1984; 1994) states that coevolutionary development has been occurring for millennia as people attempt to use physical systems to their benefit, as exemplified by this case study. In doing this

people engage in a pattern of feedback loops. While physical systems respond to human decisions, social systems respond to the ensuing changes from the physical system, which the physical system then responds to with yet another set of changes. Over time, the complexity of this pattern renders it nearly impossible to attribute any particular development to a specific feedback loop as the two systems have become completely intertwined.

These feedback loops between the systems can be considered to be selection pressures as they can have a determining impact on future possibilities for the systems. This, then, is the coevolutionary argument about social and physical complex adaptive systems in a nutshell. While the core of coevolution, namely reciprocal selection, concerns content (i.e., what is selected and what are the consequences to the state of the system), the coevolutionary approach adopted by Norgaard, among others, introduces the elements of structure (complex adaptive systems and agency) and elements of process (positive and negative feedback following deliberate selection, punctuated change, hysteresis, path-dependency and lock-in).

Consequently, a theoretical framework that allows analyzing decision-making as a coevolutionary process should take the following into account. Firstly, isolating the object of research from its environment decreases its explanatory power. Secondly, a systemic framework must take into account that there is mutual interaction between the diverse systems. Thirdly, complex causation does not stem only from the multiple causes and effects but also from erratic change. This means that the relationship between cause and effect could be altered through the occurrence of events or could lead to different developmental pathways if repeated elsewhere in time and/or location (Byrne, 2005). Fourthly, the mechanisms of coevolution can be named and mapped.

That public decision-making is not a strict hierarchy but takes place in networks is already established and there is an obvious connection between policy networks and systems as networks are systemic by definition (cf. Klijn & Snellen, 2009; Morçöl & Wachhaus, 2009). This perspective can be further refined from a complexity theory perspective. Empirically, the actors in cases define the boundaries of the systems or networks. For example, they define the physical system by deciding what is included and what is not included. In this case study, there was a clear tendency among policy makers during the early stages to use a narrow definition that centered around the water itself, whereas for example the environmental pressure groups used a broader definition, including the land behind the dikes. These definitions change over time. Besides this, actors also define their own system with people who are included or excluded. The case shows that the system of officials evolved over time with people changing their opinion about the operation. The ambiguous stance of Niedersachsen and Schleswig-Holstein is an example of how officials change their perception and thus change the constitution of the policy system. Consequently, the boundaries of systems are porous and evolve along the system definitions of actors. The act of defining the system by actors in cases must be understood in order to understand decision-making processes, rather than trying to arrive at second-order boundary judgment (Cilliers, 2001). The actors' perception of what defines the system is decisive in determining what is included in the system, as it is from this perception that they act accordingly.

At the heart of coevolutionary processes lies the concept of reciprocal selection. The concepts of 'feedback' and 'selection pressure' appear to be closely related but the difference between them is not purely semantic. Coevolution thrives on positive feedback loops (Norgaard, 1994) as they provoke adaptation and thus, a change in the state of systems. Feedback therefore becomes selection pressure as a response to an incentive leading to change. This poses two questions: what is being selected and how is it selected?

The answer to the first question is that the future state of a complex adaptive system is being selected. The adaptation to a certain incentive means a change in the systems' states but, following the processes of path-dependency and lock-in, this in turn means that certain

sequences of systems' states become possible while others are relegated outside the range of what is feasible. This process applies to both physical and social systems. For example, the decision to deepen the river denies it the possibility of silting up and meandering to a different course. Conversely, a physical change such as the rapid increase in sediment accumulation pushes officials into a reactive role as they face an unfavorable situation to which they have to respond regardless of their earlier intentions. Reciprocal selection therefore means that the future state of systems is determined by selection pressures from *both systems*.

The answer to the second question, namely how the future state is selected, is also of importance here. Selecting options is preceded by creating variety of options. Aldrich and Ruef (1999) note that intentional variation is driven by active attempts by actors to find solutions while blind variation occurs through events independent from actors' behavior. In coevolution, the creation of variety and selecting variety is part of the same feedback loop (Foster & Hölz, 2004; Hrebiniak & Joyce, 1985).

The case study illustrates that actors struggle with determining the impact of their decisions. They argue that favorable outcomes are due to their decisions whereas unfavorable outcomes are attributed to chance or the unwanted actions of others. The discussions about the cause of the sudden sediment accumulation are an example of that. This ostensible absence of clear causation may give the impression that, while intended selection is perceptible, certain variation cannot be related and is, therefore, blind. The argument here is that complex causation could indeed create that impression but that variation in the future can still be triggered by current selection, even when this variation is unintended, unobserved and unexpected. Consequently, there are two basic types of reciprocal selection: perceptible and blind, each exerting its own selection pressures on the systems.

Perceptible selection is an intended result of choices made by actors. They assess the current situation, define a desired state of the system and draw up a solution to change the current situation into the desired situation. For example, HPA aims to receive larger ships, they deem the current depth insufficient to achieve this aim and consequently make a plan for the deepening of the navigation channel that they execute. In other words, they exert a selection pressure on the physical system. This creates a renewed situation from which they can continue to work, i.e., it determines the variation available to actors at a later stage.

However, the cause of this selection pressure is not necessarily clear. Although a clear and intended change in the other system could occur, it is also possible that a certain action may lead to no changes or unintended changes. The timeframe of these changes can be erratic, with results sometimes appearing immediately while there may be long delays in others cases. Due to the limited information capacity of actors, the consequence of a particular action may appear to be detached. Because this consequent action also results in changes to a situation and determines the variation available at a later stage, this is blind selection, i.e., variation that is seemingly detached from the act of selecting but that, in fact, is not. For example, changes to the sediment transport of the river can be attributed to several decisions made by officials, but its exact causation is almost impossible to determine. However, it still pressures them to act even though its cause is obscure and might, in fact, be a result of the decisions made by the same people.

The erratic nature of blind selection can be explained by processes known in complexity theory. Selection pressures constitute feedback loops that can be positive or negative and can lead to the occurrence of change, punctuated equilibrium, hysteresis, path-dependency and lock-in effects, all of which render the result different in time and place from the initial intention (Gerrits, 2008). The resulting situation defines the degree of freedom available. Selection can therefore be blind because of the disposition of processes in complexity while still being reciprocal because of the mutual influence of systems to determine their future states. The nature of perceptible and blind reciprocal selection as part of coevolutionary processes raises the ostensible complexity and

inherent uncertainty experienced by actors.

Taken together, all selection pressures present a complex puzzle to the policy system. It has to make decisions regarding the physical system but some demands, wishes and practical possibilities are not compatible. In order to structure the information from the selection pressures they are subject to and to develop an assessment they can act upon, officials apply two selection mechanisms, namely boundary judgments and diversity of information. Each of these two mechanisms can be subdivided in two more subtypes. Within the selection mechanism of boundary judgments, officials can decide on their connections with other people, most notably opponents, and their composition, i.e., who are allowed to participate in the actual decision. Within the selection mechanism of diversity, officials can decide on the research it requires and the scope of the project it intends to initiate. These selection mechanisms vary as the case evolves.

Conclusions

Following the tremendous societal resistance and physical problems, the authorities started to realize that the chosen route would not take them much closer to a new deepening. Consequently, they started a mediation process and started to rethink their continuous economic utilization of the river. Although it does not lead to a major change, yet, it is significant that for the first time they developed a long-term vision for the region and for the first time listened to input from opponents. This does not mean that all is now well but there are signs that some changes are taking place. The coevolutionary framework in this research shows that such a rethinking is necessary because officials are not deciding over passive systems. Rather, they are entangled in patterns of reciprocal selection and they can be both architects of a new future and victims of their own decisions. Since the physical system does not necessarily comply, officials may be subjected to multiple pressures that they can only partially control. The outcomes of their decisions are often different from the original aim because the return is often disproportional to the action—as shown by the dramatic increase of sediment accumulation. In making decisions, officials are subjected to blind selection stemming from earlier decisions that have adverse effects, accidental changes and events. The relationship between these decisions and the actual outcomes is obscured because of complex causation. Future policy options are limited not by only by perceptible and deliberate choices made by officials but, above all, by the actual physical developments—especially in this case where the new stable state proves to be persistent. To complicate matters further: there is an erratic relationship between decisions and outcomes. Responses to decisions do not evolve regularly but instead, display a punctuated nature with changes taking place elsewhere in time. Therefore, new situations can be relatively unexpectedly, especially when the new situation is unintended.

This creates uncertainty. Officials respond by altering the selection mechanisms and with that, the disposition of the policy system. There are two archetypes of responses.

The *singular* response is characterized by the desire to connect with those who support the officials' goals and by excluding those who oppose them. This results in a narrow scope of the project and consequently, in research aimed exclusively at finding the means to that end. The main reason for this approach is an attempt to keep the project under control as it is considered complex enough as it is without distracting factors. Any perceived threat to the original goal is actively diverted away. The case study shows this process as initial response to safeguard the original plan to carry out another deepening.

However, such an approach can be rendered intolerable if the selection pressures that were initially diverted backfire. Officials are then forced to alter their regime. The second type response is characterized by a *composite* nature. Officials then connect with other actors in order to expand the diversity of ideas and goals in the process. This results in a debate that questions the scope, subsequently taking into account more than one aspect of the physical system. Consequently, research is also aimed at exploring options rather than simply finding the means to a given end.

The case study shows that composite characteristics are encompassed within the singular responses but not always unlocked. Both types of responses are built around multiple actors, which creates the potential for more diversity. A more composite nature is also not the final state as officials can convert (back) into singularity. Change or consolidation of regime is induced by actual unfavorable events or by the perceived imminent risk of such changes.

While a change or consolidation of singularity or composition may be a deliberate response, it has also been observed that both types of responses have the capacity to reinforce their nature unintentionally. The singular response is driven by its self-referential nature that reconfirms its workings while the composite response is driven by further dissipation in an attempt to be comprehensive. So it appears that decision-making processes are partly uncontrollable by the decision-maker. Possible future states of systems be compromised through adverse, unintended results and events, and the nature of the responses can also change partly uncontrollably as a singular response can make people blind for its singularity and a composite response may not be able to keep diversification that is created under control. However, singular responses are less likely to take into account all the possible future states of the physical system. But composite responses can not fully avoid the possible occurrence of unforeseen and unfavorable change. Only the probability of such developments can be reduced. However, reframing decision-making as coevolution helps officials understanding that decision-making is a matter of reciprocal selection, with the results not being fully determined by their intended selections but rather, emerging from the entire complex process of reciprocal selections.

References

Aldrich, H.E. and Ruef, M. (1999). *Organizations Evolving*, ISBN 0803989199.

Byrne, D. (2005). "Complexity, Configurations and Cases," *Theory, Culture & Society,* ISSN 0263-2764, 22(5): 95-111.

Cilliers, P. (2001). "Boundaries, Hierarchies and Networks in Complex Systems," *International Journal of Innovation Management,* ISSN 1363-9196, 5(2): 135-147.

Foster, J. and Hölz, W. (Eds.). (2004). *Applied Evolutionary Economics and Complex Systems*, ISBN 1843763699.

Gerrits, L.M. (2008). *The Gentle Art of Coevolution; a complexity theory perspective on decision making over estuaries in Germany, Belgium and the Netherlands*, ISBN 9789075289169.

Gils, M.K.A., Gerrits, L.M. and Teisman, G.R. (2009). "Non-Linear Dynamics in Port Systems: change events at work." in G.R. Teisman, Buuren, A., Gerrits, L.M. *Managing Complex Governance Systems*, ISBN 9780415459730.

Hrebiniak, L. G. and Joyce, W. F. (1985). "Organizational Adaptation: Strategic Choice and Environmental Determinism," *Administrative Science Quarterly,* ISSN 0001-8392, 30(3): 336-348.

Hooke, J. M. (1999). Decades of Change: Contributions of Geomorphology to Fluvial and Coastal Engineering and Management. *Geomorphology,* ISSN 0169-555X, 31(4), 373-389.

Klijn, E.H., Snellen, I. (2009). "Complexity Theory and Public Administration: A Critical Appraisal" in G.R. Teisman, Buuren, A., Gerrits, L.M. *Managing Complex Governance Systems*. ISBN 0415459737.

Morçöl, G. and Wachhaus, A. (2009). "Network and Complexity Theories: A Comparison and Prospects for a Synthesis," *Administrative Theory & Praxis,* ISSN 1084-1806, 31(1): 44-58.

Norgaard, R. B. (1984). "Coevolutionary Development Potential," *Land Economics,* ISSN 0023-7639, 60(2): 160-173.

Norgaard, R. B. (1994). *Development Betrayed; The End of Progress and a Coevolutionary Revisioning of the Future*, ISBN 0415068622.

Odum, E.P. (1971). *Fundamentals of Ecology*. ISBN 0721669417.

Otter, H.S. (2000). *Complex Adaptive Land Use Systems: an interdisciplinary approach with agent-based models,* ISBN 9051668171.

Sanderson, S.K. (1990). *Social Evolutionism. A Critical History*, ISBN 1557860734.

Turner, R.K. (2000). "Integrating Natural and Socio-economic Science in Coastal Management," *Journal of Marine Systems,* ISSN: 0924-7963, 25(3 - 4): 447-460.

Acknowledgments

The author thanks Geert Teisman and Jurian Edelenbos for their accompaniment during this research and Jack Meek for his review.

Lasse Gerrits M.Sc. BA was a researcher at TNO Built Environment and Geosciences and a Ph.D. student at the Department of Public Administration at Erasmus University Rotterdam between 2003 and 2008. He now works as an Assistant Professor in Public Administration. His main research focuses on the developing and applying complexity theory in the realm of public decision-making and he runs a Master's program called Governance & Management of Complex Systems.